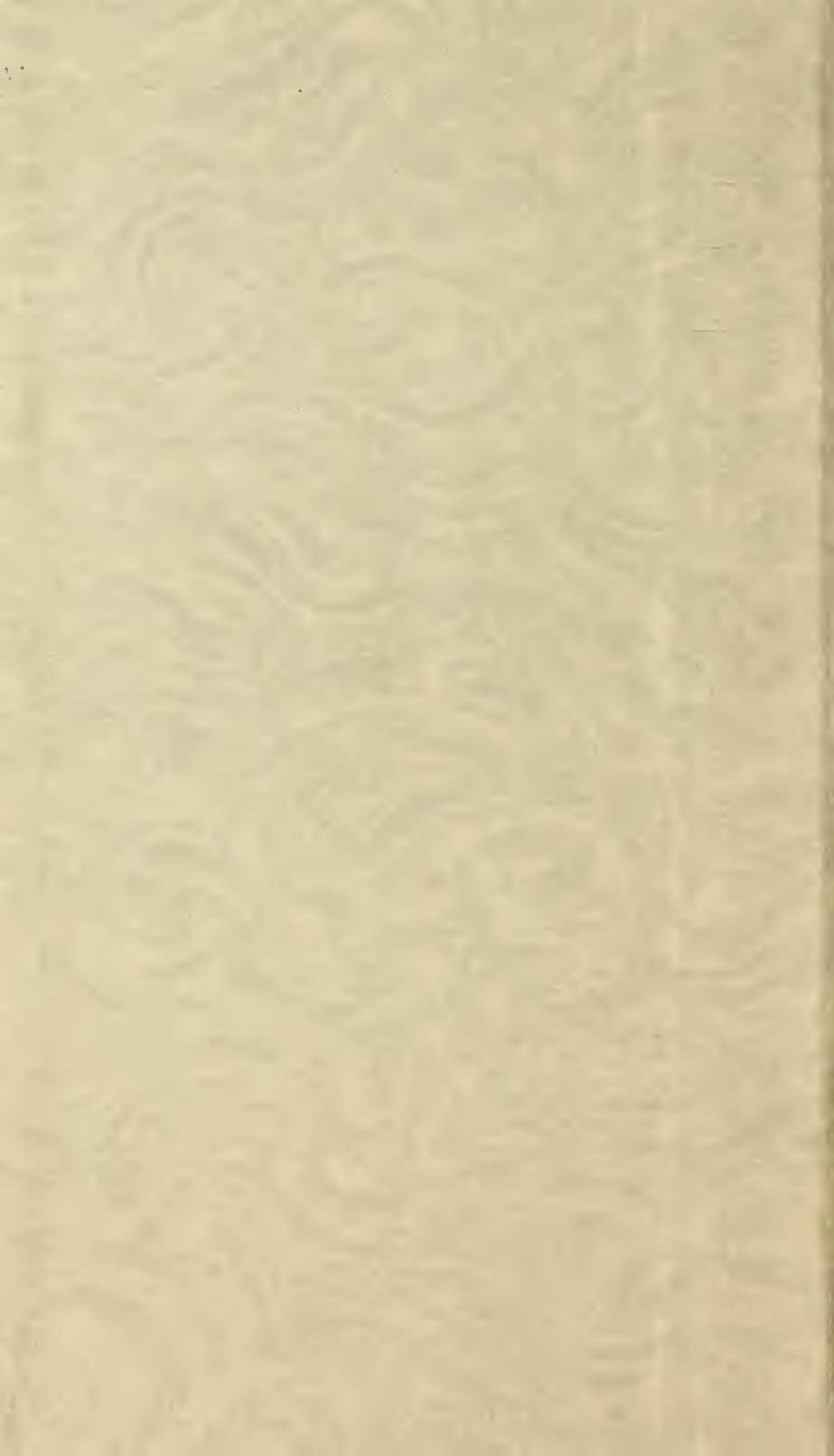


Clemson University



3 1604 019 891 441



Clemson College Library





Digitized by the Internet Archive  
in 2013



DEPARTMENT OF THE INTERIOR

BULLETIN

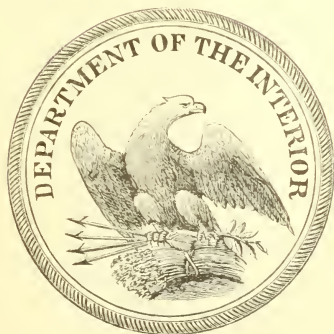
OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 180

SERIES A, ECONOMIC GEOLOGY, 11



WASHINGTON

GOVERNMENT PRINTING OFFICE

1901





JOSEPH HYDE PRATT

UNITED STATES GEOLOGICAL SURVEY

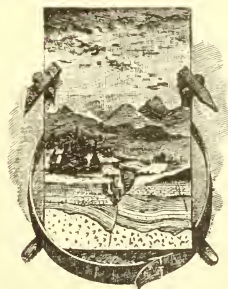
CHARLES D. WALCOTT, DIRECTOR

---

THE  
OCCURRENCE AND DISTRIBUTION  
OF  
CORUNDUM IN THE UNITED STATES

BY

JOSEPH HYDE PRATT



WASHINGTON  
GOVERNMENT PRINTING OFFICE  
1901



# CONTENTS.

	Page.
Introduction .....	9
Modes of occurrence of corundum .....	11
Corundum in peridotites .....	11
Corundum in biotite, contact on saxonite .....	19
Corundum in enstatite .....	20
Corundum in serpentine .....	20
Corundum in chlorite-schist .....	21
Corundum in amphibolite .....	21
Corundum (emery) in amphibolite at Chester, Mass .....	23
Origin of the emery .....	25
Corundum in norite .....	26
Corundum in basic minette .....	28
Corundum in andesite .....	29
Corundum in syenite .....	30
Corundum in amphibole-schist .....	31
Corundum in gneiss .....	33
Corundum in mica-schist .....	34
Corundum in limestone .....	36
Corundum in cyanite .....	36
Summary of corundum occurrences .....	37
Distribution of corundum .....	37
Sapphire or corundum gems .....	38
Oriental ruby .....	39
Oriental sapphires .....	46
North Carolina sapphires .....	46
Montana sapphires .....	47
Rock Creek sapphires .....	50
Cottonwood Creek sapphires .....	51
Yogo Gulch sapphires .....	52
Etching figures .....	54
Corundum .....	55
North Carolina .....	55
Macon County .....	55
Sheffield mine .....	58
Clay County .....	58
Buck Creek or Cullakeenee mine .....	58
Blue Ridge corundum tracts .....	59
Jackson County .....	61
Georgia .....	63
Laurel Creek mine .....	63
Track rock mine .....	65
Foster mine .....	65
South Carolina .....	66
Pennsylvania .....	66
Montana .....	66

Distribution of corundum—Continued.		Page.
Emery .....		67
Massachusetts .....		67
New York .....		70
North Carolina .....		72
Methods of mining corundum .....		72
Methods of cleaning corundum .....		74
Uses of corundum .....		75
Vitrified wheel .....		77
Chemical wheel .....		77
Cement wheel .....		78
Other uses .....		78
Corundum localities in the United States .....		79
Alabama .....		79
California .....		79
Colorado .....		80
Connecticut .....		80
Delaware .....		80
Georgia .....		80
Maryland .....		81
Massachusetts .....		82
Montana .....		82
Nevada .....		82
New Jersey .....		82
New York .....		82
North Carolina .....		83
Pennsylvania .....		86
South Carolina .....		87
Utah .....		87
Virginia .....		87
Alaska .....		88
Corundum localities in foreign countries .....		88
Canada .....		88
India .....		89
Turkey .....		91
Grecian Archipelago .....		91
Other localities .....		91

## ILLUSTRATIONS.

	Page.
PLATE I. Outcrop of peridotite at Buck Creek, Clay County, N. C. ....	10
II. A, Bed of ruby-bearing gravel at Caler Fork, Cowee Valley, Macon County, N. C.; B, Rubymine at Cowee Valley, N. C. with plant for washing the gravels in the foreground .....	40
III. Ruby crystals from Cowee Valley, Macon County, N. C. ....	42
IV. Map showing location of sapphire deposits in Montana .....	46
V. Sapphire crystals, from Yogo Gulch, Fergus County, Mont. ....	52
VI. Map showing location of the peridotite rocks and corundum localities of North Carolina and Georgia .....	54
VII. General view of the peridotite formation at Corundum Hill, Macon County, N. C. ....	56
VIII. The "Big vein" at Corundum Hill, between the peridotite and gneiss, Macon County, N. C. ....	56
IX. Upper end of big cut at Corundum Hill mine, Macon County, N. C. ....	58
X. Open cut on a dunite vein at the Mincey mine, Macon County, N. C. ....	58
XI. A, General view of the Buck Creek corundum mine and peridotite formation, Clay County, N. C.; B, Dunite vein of corundum in the peridotite formation at Buck Creek, Clay County, N. C. ....	60
XII. Open cut on peridotite-gneiss contact at Laurel Creek, Georgia, with shaft house in foreground .....	64
XIII. A, Peridotite formation at Laurel Creek, Georgia; B, Dunite vein of corundum at Laurel Creek, Georgia .....	66
XIV. A, Corundum mill at Cullasagee, Macon County, N. C.; B, Interior view of corundum mill at Cullasagee, Macon County, N. C. ....	74
Fig. 1. Ideal cross section of a corundum contact vein at the Corundum Hill mine, Macon County, N. C. ....	13
2. Ideal cross section of a corundum-dunite vein at the Corundum Hill mine, Macon County, N. C. ....	15
3. Ideal vertical cross section of a mass of peridotite soon after its intrusion in gneiss .....	16
4. Ideal vertical cross section showing a somewhat gradual transition from corundum to peridotite .....	17
5. Map of the Buck Creek peridotite area, showing the relation of the amphibolite dikes .....	22
6. Ideal vertical cross section of corundum in amphibolite at Hunters, Iredell County, N. C. ....	23
7. Corundum crystal showing concentric hexagons on basal plane ...	45

Fig. 8. Spokane Bar sapphire deposits, Lewis and Clarke County, Mont.....	Page. 48
9. Sapphire crystals from Missouri River bars, Montana .....	50
10. Map of the peridotite formation at Corundum Hill, Macon County, N. C.....	50
11. Map of the peridotite areas in the vicinity of Sapphire, Jackson County, N. C., showing the location of the different corundum mines .....	63
12. Map of the peridotite formation at Laurel Creek, Georgia.....	64
13. Map showing the location of the emery deposit at Chester, Mass....	65
14. Cross section of the Old mine at Chester, Mass., showing the amount of emery taken out to April, 1899.....	65

# OCCURRENCE AND DISTRIBUTION OF CORUNDUM IN THE UNITED STATES.

---

By JOSEPH HYDE PRATT.

---

## INTRODUCTION.

In obtaining data for this paper many corundum localities were visited, especially those that were thought to carry the mineral in commercial quantity. Although all the occurrences of corundum can not be described in detail, they are all mentioned in the tabulated list of localities, page 79.

Considerable activity in corundum mining has sprung up within the last few years, and several new occurrences of corundum in quantity have been brought to light, those of special note being in Ontario, Canada, where the corundum occurs in a syenite, and in North Carolina and Georgia, where it occurs in a gneiss or a quartz-schist.

The corundum localities in the United States are, with the exception of those in Montana, Colorado, and California, limited to the Appalachian region, the mineral having been found at various points throughout nearly its entire length. The mining of corundum has been, however, confined to a narrow section of the southern portion of that region, i. e., to northeastern Georgia and southwestern North Carolina, with the exception of the emery mines at Chester, Mass.

Often a distinction is made between emery and corundum, many persons not recognizing emery as a variety of corundum. There are three names in constant use to designate the varieties of corundum: (1) Sapphire, which includes all corundums, of whatever color, that are transparent to semitransparent; (2) corundum, including the translucent to opaque varieties of all colors; (3) emery, which is a mechanical admixture of corundum and magnetite or hematite. The last two varieties are those used in the arts for abrasive purposes, emery being used in very much larger quantities than corundum. It is of course the presence of corundum in the emery that gives to it its abrasive qualities and makes it of commercial value, and the abrasive efficiency of emeries varies according to the percentage of corundum they contain.

Any corundum that is transparent is included under the head of sapphires, although many of these have distinct names in the gem trade. The blue sapphire is known as the oriental sapphire, the red

sapphire as the oriental ruby, the green sapphire as the oriental emerald, the yellow sapphire as the oriental topaz, and the purple sapphire as the oriental amethyst. There are also pink and white sapphires. The corundum gem or sapphire localities are usually distinct from the corundum localities, although very handsome gems have been found where the corundum was mined for abrasive purposes, notably at the Corundum Hill mine, Cullasagee, N. C.

Corundum as it is mined for abrasive purposes occurs as (1) sand, (2) crystal, or (3) gravel and block corundum. Sometimes all three types are found in the same deposit. The sand corundum consists of small grains or fragments of the mineral scattered through the vein. The crystal corundum consists of crystals up to 3 inches in length. Often these crystals have parting planes so thoroughly developed that, in crushing, the corundum breaks up into regular rhombohedrons, this breaking continuing to even the finer sizes and causing the grains of corundum to crumble when in use. This persistent regular breaking of the corundum destroys its cutting efficiency, for it is the irregular fracture that produces the best cutting edge. The block variety often occurs in masses of almost pure corundum from 10 to 1,000 pounds in weight. Again it occurs in large masses intimately associated with hornblende, feldspar, etc., making a rock which is tough and is difficult to work. Frequently the only way to break the masses is to build fires over them and then suddenly cool them by pouring water upon them. The parting planes are at times very noticeable in the block corundum, and are, as in the crystal corundum, detrimental to the commercial product. The parting planes are not lines of cleavage, but are planes developed in the mineral by synthetic twinning, usually parallel to the unit rhombohedron.

It is the hardness of corundum that makes it of so great value as an abrasive. Next to the diamond it is the hardest mineral known, having a hardness of 9, while the diamond has a hardness of 10. Garnet, which is sometimes used as an abrasive, has a hardness of but 7 to 7.5. Corundum varies slightly in hardness; the sapphire varieties are generally considered the hardest, and of these the blue stands at the head. Some corundum has been observed that was readily scratched with a knife, as that from Acworth, Ga. The hardness of a corundum is often misjudged because, when made into a wheel, it does not cut so well as another, when in reality the degree of hardness may be the same in both cases, but the cutting efficiency of one surpasses that of the other.

The theoretical composition of corundum is alumina ( $\text{Al}_2\text{O}_3$ ); but with one or two exceptions all corundums that have been examined vary from this by containing a small percentage of other constituents, principally silica ( $\text{SiO}_2$ ), water ( $\text{H}_2\text{O}$ ), and ferric oxide ( $\text{Fe}_2\text{O}_3$ ). Nearly all corundums contain water, the amount varying from a trace to 2 per cent or more. The amount of silica and ferric oxide varies also, some corundums containing neither of these constituents and some



OUTCROP OF PERIDOTITE AT BUCK CREEK, CLAY COUNTY, N. C.



containing as much as 5 per cent of one or the other. The purest forms of corundum that have been analyzed are the sapphire or gem varieties, which sometimes show over 99.5 per cent of alumina.

All corundums do not behave alike when heated to the high temperature necessary for the manufacture of vitrified wheels. While most corundums can, if properly cleaned, be used in the manufacture of these wheels, some will, when heated, crumble to a powder. It is, therefore, very essential, before beginning to mine a corundum deposit, to thoroughly test the ore and ascertain its adaptability to the manufacture of vitrified and other wheels.

### MODES OF OCCURRENCE OF CORUNDUM.

Corundum was formerly regarded as occurring sparingly in nature, and in only a few types of rocks, but it is now known to occur rather widely, and instead of being in quantity in the basic magnesian or peridotite rocks only, it has been found in abundance in syenites, in gneisses, and in schists. Although occurring in many of the crystalline rocks, it has been observed as a rock constituent in only a few of them. In some cases it is an original constituent of the rock, and in other cases it has been formed later, during the process of metamorphism.

In the United States corundum is known to occur in the following rocks: In peridotite (dunite and saxonite), in biotite contact on saxonite, in enstatite, in serpentine, in chlorite-schist, in amphibolite, in norite, in basic minette, in andesite, in syenite, in amphibole-schist, in gneiss, in mica-schist, in limestone, and in cyanite. These modes of occurrence are described below in the order in which they are mentioned.

#### CORUNDUM IN PERIDOTITES.

Extending from Tallapoosa County in east-central Alabama to Trenton, N. J., there is a narrow belt which contains disconnected outcrops of peridotite rocks; north of New Jersey (in New York, Connecticut, Massachusetts, New Hampshire, and Maine) the outcrops are fewer and do not form a continuous belt. It is in the southern portion of this belt that these rocks have reached their greatest development, in some localities outcropping over an area of several hundred acres. In North Carolina and in the more southern portion of the belt the prevailing type of the rock is dunite, while in the northern portion the secondary rocks, serpentine and talc, are prominent. Pl. I is a reproduction of a photograph of an outcrop of dunite at Buck Creek, Clay County, N. C.

Throughout nearly the entire southern portion of the belt the peridotite rocks show a freshness to almost the surface of the exposures, and there are few localities where there is any considerable area of peridotite entirely altered to serpentine. Under the microscope thin sections of the dunite show an alteration to serpentine between the

particles of dunite. These peridotite rocks have been shown to be of igneous origin.<sup>1</sup> The blunt lenticular form in which they are found would be difficult to associate with any origin but that of an intruded igneous mass, which would also account for the apophyses that have been observed extending into the inclosing gneiss. At Webster, Jackson County, N. C., a large block of gneiss is completely inclosed by the peridotites in such a manner as could be attributed only to the intrusion of the latter while in a molten condition. The line of separation of the peridotites and the gneisses is always sharp, and there is no transitional zone from the acid gneiss to the basic peridotite. Under the microscope the latter rock shows the granular structure characteristic of plutonic origin, the grains fitting perfectly into one another without cementing material.

Associated with all these peridotites is the mineral chromite, which occurs as disseminated particles near the borders of the lenticular masses of the peridotites. There is very little carbon found associated with these rocks, and what has been observed is unquestionably of secondary origin.

Until recently the common occurrence of corundum (not including emery), and the occurrence in which the mineral had been found in commercial quantity, was in association with these basic magnesian rocks, peridotites, principally dunite. The country rock that is commonly in contact with the peridotite is a hornblende-gneiss, but these peridotite formations have also been found in contact with a biotite-gneiss and with a mica-schist. Where the country rock is a gneiss it is usually considerably decomposed near the contact, and, while retaining the appearance of the unaltered rock, it readily crumbles to pieces when handled. The peridotite is also more or less altered, the change being usually to serpentine.

The corundum is not an accessory mineral in these peridotites, but is either concentrated near the contact of the peridotite with the other country rocks or in pockets within the peridotite formation. A series of alteration products has been developed in this contact zone, so that the corundum is not found in direct contact with the peridotite, but is separated by intermediate zones of chlorite, enstatite, etc. Chlorite and vermiculite are usually developed between the corundum and the gneiss. For convenience, the occurrences of the corundum in these alteration products between the peridotite and the gneiss are designated contact veins, and those wholly within the peridotite dunite veins.

In a cross section of a contact vein extending from the gneiss to the peridotite (dunite) the following sequence is often observed:

*a.* Gneiss, hornblendic or micaceous, apparently unaltered.

*b.* Gneiss with same general appearance as *a*, but so decayed that the particles readily separate from one another.

---

<sup>1</sup> Elisha Mitchell Sci. Soc. Jour., Part II, 1895, p. 35, and Am. Jour. Sci., 4th series, Vol. VI, 1898, p. 50.

*c.* Yellowish vermiculites, varying considerably in thickness, the maximum being 6 to 8 inches; in places absent, so that *b* comes directly in contact with *d*; where present, *c* often merges into *d*.

*d.* Green chlorite, varying in thickness much like *c*, and in places absent.

*e.* Chlorite and corundum, sometimes with a little vermiculite. In places this mass may be largely corundum, and it is what is called the "corundum vein," varying in thickness from a few inches to 12 or 15 feet.

*f.* Green chlorite: so far as observed always present, and varying in width from 1 to 12 inches.

*g.* Enstatite; in places hard and compact, and in widths of several feet; usually merges into *h*.

*h.* Talcose rock, usually fibrous, varying in thickness from a few inches to several feet.

*j.* Dunite, more or less altered, friable, and stained with ferric oxide.

*k.* Dunite, apparently unaltered, quite extensive.

Between *h* and *j* a seam of yellowish clay (*i*) is sometimes observed which often contains a narrow seam or fragments of chalcedony.

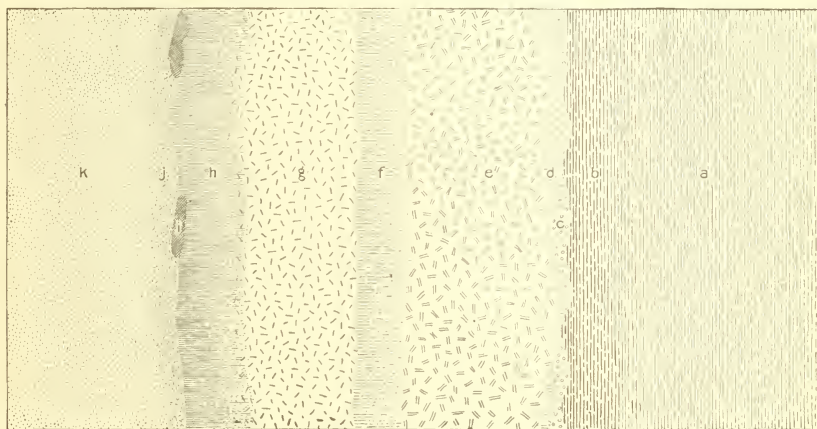


FIG. 1.—Ideal cross section of a corundum contact vein at the Corundum Hill mine, North Carolina. *a*, fresh and unaltered gneiss; *b*, decayed and unaltered gneiss; *c*, vermiculites; *d*, green chlorite; *e*, corundum-bearing zone; *f*, green chlorite; *g*, enstatite; *h*, talcose rock; *i*, clay; *j*, altered dunite; *k*, unaltered dunite.

From what could be learned by actual observation and inquiry among the miners, *c* and *d* are sometimes absent, and when this is the case, *e*, a mixture of chlorite, vermiculite, and corundum, is seemingly in direct contact with *b*. The chlorite, however, on the dunite side of the section is constant. The thickness of the several zones (*a*, *b*, *c*, etc.) in such sections varies greatly at different places, and the distance across the sections may be said to vary at different points, even in the same region, from a few feet to 30 or 40 feet. The accompanying diagram (fig. 1) represents the cross section of a contact vein observed at the Corundum Hill mine, Cullasagee, Macon County, N. C.

In the diagram *a* represents gneiss, apparently fresh and unaltered, passing into *b*, which has somewhat the appearance of the unaltered gneiss, but is so decayed that the particles readily separate from

one another; *c* represents a narrow zone of vermiculites that is sometimes entirely lacking; *d*, a green chlorite (clinochlore) partially decomposed and forming the vermiculites of *c*; *e*, the corundum-bearing zone, a mass of the green chlorite with crystals and fragments of corundum disseminated through it; *f*, another zone of the green chlorite; *g*, a mass of grayish, interlocking, crystalline sheaves of enstatite that merge into *h*; *h*, a fibrous talcose rock which passes into *j*; *j*, an altered dunite that is somewhat friable and stained with ferric oxide; *k*, a hard and apparently unaltered dunite. Between *h* and *j* is a mass of soft, yellowish clay (*i*) containing fragments of chalcedony.

The line of contact between the zone of alteration products and the gneiss was very sharp and distinct in all the contact veins examined. The minerals developed between the corundum-bearing zone and the dunite are in great abundance and differ from those between that zone and the gneiss.

In a cross section of a dunite vein at a shaft near the southern part of Corundum Hill, in a distance of from 20 to 25 feet, the following has been observed:

1. Dunite, hard and apparently unaltered.
2. Dunite, somewhat friable and discolored, passing into 3.
3. Talcose rock, fibrous, merging into 4.
4. Enstatite, grayish and somewhat fibrous.
5. Green chlorite, 6 to 15 inches in width.
6. Green chlorite, corundum, and spinel, 6 to 8 feet wide.
7. Chlorite, same as 5.
8. Enstatite, same as 4.
9. Talcose rock, same as 3.
10. Dunite, same as 2.
11. Dunite, same as 1.

The similarity of the two parts of the vein separated by the corundum zone, as already described and as illustrated in fig. 2, is very apparent.

In fig. 2, 1 and 11 represent the apparently unaltered dunite; 2 and 10 represent dunite somewhat friable and stained and passing into 3 and 9—a fibrous talcose rock, often carrying a green actinolite and some green chlorite; 4 and 8 represent a grayish, rather fibrous enstatite rock, which merges into 3 and 9; 5 and 7 represent a green chlorite, which passes into 6—a mass of chlorite, corundum, and spinel.

Although the section just described is a special case, it was observed that all of the dunite veins had the same character on both sides of the corundum-bearing zone. As has been already stated, either a talcose or a serpentine rock may be the limit of the cross section. In one of the dunite veins at Corundum Hill near the west end of the outcrop, the zone of corundum, chlorite, and vermiculites is in direct contact, both on the hanging and on the foot wall, with a serpentine rock. This zone is divided—in one place almost pinched out—by a mass of serpentine.

At all of the corundum localities examined a careful search has been made to find the corundum directly surrounded by the peridotite, but it has been thus observed at only one locality—the Egypt mine, on the western slope of the Sampson Mountains, in Yancey County, N. C. The few specimens obtained were collected by Mr. U. S. Hayes, who developed the corundum property in that section. One specimen shows a prismatic crystal of the corundum surrounded by a granular peridotite (dunite), but with none of the chlorite minerals which usually intervene. The dunite is not quite fresh, but is stained a yellowish brown by iron oxide and is rather friable. On the basal surfaces of the corundum a little muscovite is developed. This has been observed on corundum from other localities.

Spinel has been found at a number of the corundum veins, and in

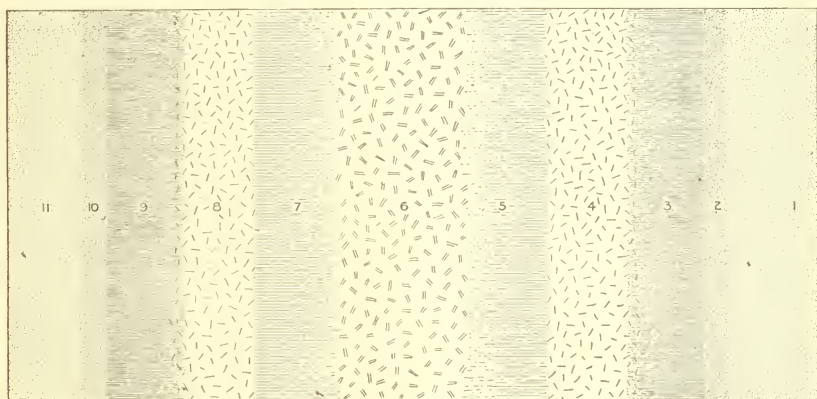


FIG. 2.—Ideal cross section of a corundum-dunite vein at the Corundum Hill mine, Macon County, N. C. 1, hard and unaltered dunite; 2, friable and discolored dunite; 3, talcose rock; 4, enstatite; 5, green chlorite; 6, green chlorite, corundum, and spinel; 7, green chlorite; 8, enstatite; 9, talcose rock; 10, friable and discolored dunite; 11, dunite.

a few cases it is very intimately associated with the corundum. At the Carter mine, near Demoerat, Buncombe County, N. C., the corundum is found, in masses of a white and pink color, intergrown with a greenish-black spinel. The masses of corundum and spinel are partially surrounded by a deep-green chlorite, which has also been developed in places between the corundum and the spinel, although this contact of the corundum and the spinel is usually very sharp and distinct. A massive, coarsely to finely granular spinel is found at the Corundum Hill mine, Macon County, N. C., which has disseminated through it small grains and fragments of pink and white corundum.

The mineral chromite, which has always been found associated with these peridotite rocks, occurs sparingly in many of the corundum veins. It is a well-observed fact<sup>1</sup> that where there is any quantity of

<sup>1</sup> Am. Inst. Min. Eng., Vol. XXIX, 1899; February meeting.

corundum found in the peridotite rocks there is a scarcity of chromite, and where there is a large quantity of chromite there is a scarcity of corundum.

In a recent paper<sup>1</sup> I have discussed the origin of the corundum in the peridotite rocks, and have accepted the theory that the corundum was held in solution in the molten mass of the peridotite when it was intruded into the country rock, and that as the mass began to cool it was among the first minerals to separate. In these molten magmas the more basic minerals, corundum and spinel, would be the first to

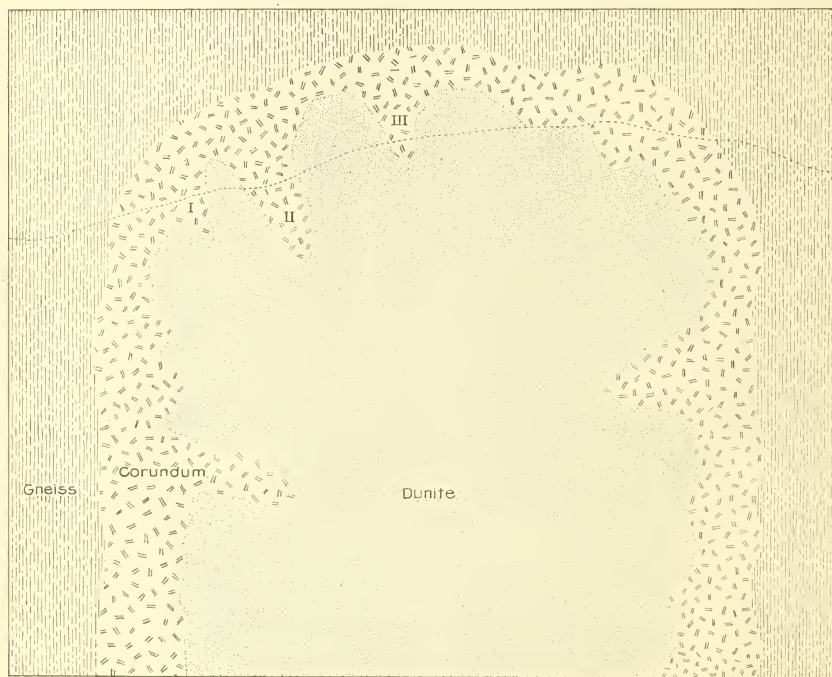


FIG. 3.—Ideal vertical cross section of a mass of peridotite soon after its intrusion in gneiss. The corundum zone is greatly exaggerated.

separate, and this separation would take place along the outer border of the mass, for there it would first cool. Convection currents would then tend to bring into this outer zone a new supply of material carrying alumina, and when this zone was reached crystallization would take place and the alumina would be deposited as corundum.

Fig. 3 represents an ideal appearance of a vertical cross section of a mass of dunite holding corundum in solution, soon after its intrusion into a gneiss. In this figure the corundum zone has been greatly exaggerated, in order to illustrate better the cross section. The corundum would be concentrated toward the borders of the

<sup>1</sup> Am. Jour. Sci., 4th series, Vol. VI, 1898, p. 49.

dunite, and would make a sharp and nearly regular contact with the gneiss. The contact with the dunite would be in some places sharp and regular and in other places very irregular, and masses of the corundum would penetrate the dunite. In some cases there would be a somewhat gradual transition from the corundum to the peridotite, as represented in fig. 4. The rapid erosion to which rocks in a moun-

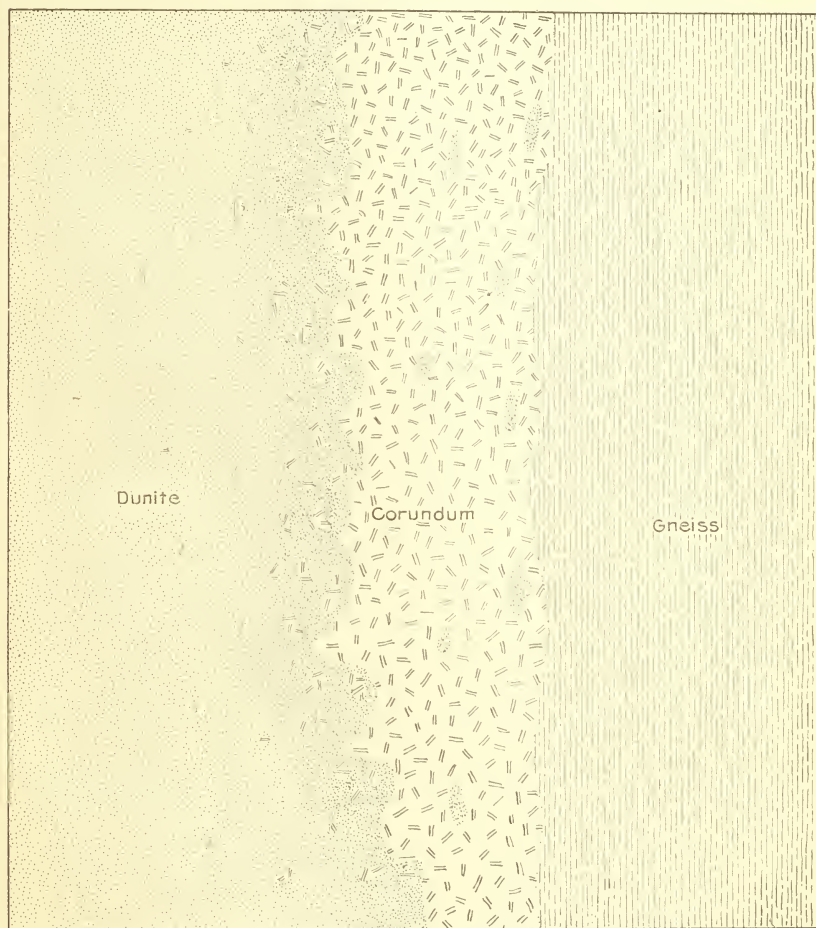


FIG. 4.—Ideal vertical cross section showing a somewhat gradual transition from corundum to peridotite.

tain region are subjected would readily wear them down to their present condition, represented by the dotted lines in fig. 3.

The corundum veins, I, II, and III, in fig. 3, which at the present time have no connection with one another, but are each separate and distinct, were at the time of their formation part of the corundum concentrated along the border of the dunite. Some of these veins would

soon be worked out, while others might be explored for a hundred or more feet without any apparent change in their width.

The most important observations leading to the adoption of this theory are: The occurrence of the corundum surrounded by granular dunite and also by serpentine; its occurrence with and surrounded by spinel; the sharp contact between the gneiss and the alteration products of the contact vein; the development, on both sides of a corundum vein penetrating dunite, of the same sequence of alteration products, which are almost identical with those on the dunite side of a contact vein; the usual narrowing and pinching of the dunite veins, the trend of which is toward the center of the mass of peridotite, while the contact vein seems to extend down indefinitely.

At a number of the corundum veins in these peridotite rocks, feldspar, which is undoubtedly one of the original minerals of the rock and not a secondary product, is found associated with the corundum. There is a marked difference in the associated minerals when the feldspar is present; the chlorite is not so thoroughly developed, and enstatite is not so common, while margarite is rather abundant and zoisite is not uncommon. These last two minerals are rarely met with free from feldspar in the corundum veins.

The separation of alumina from these peridotite magmas has given rise to some interesting problems, which I have treated in a paper<sup>1</sup> published a short time ago. A summary of the conclusions reached is given here, as they bear directly upon the occurrence of the associated minerals, spinel, chromite, and feldspar, in a corundum vein.

From what has been observed in nature and from the experiments that have been made in the laboratory, it seems that the separation of alumina as corundum from molten magmas is dependent upon the composition of the chemical compounds that are the basis of the magma, upon the oxides that are dissolved with the alumina in the magma, and upon the amount of alumina itself.

1. When the magma is composed of a magnesium silicate without excess of magnesia, all the alumina held by such a magma will separate as corundum.

2. Where there is an excess of magnesia in the magma just described, it will unite with a portion of the alumina to form spinel, and the rest of the alumina will separate as corundum.

3. Where there is chromic oxide present in a magma composed essentially of magnesium silicate (as the peridotite rocks), and only a very little alumina and magnesia are present, these, uniting, separate with chromic oxide to form the mineral chromite, and no corundum or spinel is formed.

4. When peridotite magmas contain, besides the alumina, oxides of the alkalies and alkali earths, as soda, potash, and lime, a portion of

---

<sup>1</sup>Am. Jour. Sci., 4th series, Vol. VIII, 1899, p. 227.

the alumina is used in uniting with these oxides and with silica to form feldspar.

5. There is a strong tendency for the alumina to unite with the alkali and the alkali-earth oxides to form double silicates like feldspars, whether such silicates form the chief minerals of the resulting rock or are present in relatively small amount. There is, however, little tendency for the alumina to unite with magnesia to form double silicates when the magma is a magnesium silicate.

#### CORUNDUM IN BIOTITE, CONTACT ON SAXONITE.

At the asbestos quarry near Pelham, Mass., there is a large lens of the igneous saxonite variety of the peridotite rocks penetrating the acid gneiss of the country. The saxonite is very much altered to a depth of 3 to 12 feet, when the hard nearly fresh rock is encountered, which is of a dull-black color and is made up of grains of olivine and the orthorhombic pyroxene, bronzite. The black color of the rock is due to disseminated particles of chromite and magnetite. Part of the magnetite may be due to the alteration of the grains of olivine, similar to that observed in the dunites of North Carolina, where, at the beginning of its alteration, there is a deposition of magnetite in fine grains, which forms a network of black lines often outlining the grains of olivine.

Professor Emerson has made a petrographical examination of this rock and describes it as follows:<sup>1</sup>

This is a very fresh mixture of olivine and enstatite, both dusted through with black ore, largely chromite. It is a dull-black rock of very great toughness. The olivine grains have often many crystalline faces. The enstatite is in rare, small plates, with parallel sides and irregular ends, and with a fine wavy lamination, which is often marked by lines of black ore, generally concentrated in some part of the plate, especially the center. Although nearly colorless or pale bronzy in common light, it has marked pleochroism. It is plainly rhombic, and grades into the asbestiform decomposition product in veins running through the section.

None of the anthophyllite that is so abundant in the decomposed portion of the saxonite were observed in the fresh rock.

From the fresh rock to the surface and the contact with the gneiss the saxonite is more or less completely altered, and penetrating through this there is a network of veins of anthophyllite, which are more or less asbestiform. These veins vary in width from very thin seams to 8 inches, with some that are very much wider, from which fibrous masses have been obtained 20 to 30 inches long. It is these veins of fibrous anthophyllite that constitute the asbestos quarry of Pelham.

The saxonite is separated from the gneiss by a band of bronze-colored biotite, usually 4 to 8 inches thick, but in places reaching a thickness of 4 feet. In this wider portion there are nodules or imperfect crystals of corundum of a grayish color mottled with blue.

<sup>1</sup> Mon. U. S. Geol. Survey Vol. XXIX, p. 52.

These are often wrapped with chlorite. Nodules of a black-green hornblende and an emerald-green actinolite are also found in the biotite. There has been no great quantity of the corundum found.

This zone of biotite is probably the result of contact metamorphism of the saxonite on the gneiss, and the inclosing corundum was formed at the same time. This is similar to the large quantity of corundum occurring in biotite at the contact of saxonite and gneiss at the Bad Creek mine, Sapphire, N. C. (See page 62.)

#### CORUNDUM IN ENSTATITE.

Enstatite is rather common as a secondary product at many places where the corundum occurs in peridotite, and is thus an associate of corundum at these localities. Occurrences are rare, however, of corundum in an enstatite that is the original rock. Where thus found the rock is made up chiefly of the orthorhombic pyroxene, enstatite, in bladed interlocking crystals of a grayish color. It is always more or less decomposed into talc.

At the Rattlesnake mine, Sapphire, Jackson County, N. C., and on the West Fork of the French Broad River, in Transylvania County, N. C., corundum has been found sparingly in the borders of an enstatite rock.

Enstatite rocks are somewhat common in North Carolina, but accessory minerals in them are rare, and the most common one observed is chromite, in small grains.

#### CORUNDUM IN SERPENTINE.

At a number of peridotite localities in North Carolina and Georgia crystals and fragments of corundum have been found that were surrounded by serpentine, but nowhere in this southern section of the peridotite belt has corundum been found associated with the larger masses of serpentine. In Chester and Delaware counties, Pa.,<sup>1</sup> there is a long belt of serpentine rocks, part of which, at least, have been derived from peridotite rocks, and in connection with these, in the eastern part of Chester County and the western part of Delaware County, corundum has been found. In this, as in the peridotite, the corundum occurs near the contact of the country rock. Considerable plagioclase feldspar is associated with the corundum in the vein in a manner somewhat similar to the occurrence of this mineral at the Cullakeence mine, Buck Creek, Clay County, N. C. In the South corundum has not been found as constantly associated with the serpentines as it is with the peridotites, but chromite is found very abundantly with many of them.

Cutting through the serpentines on the eastern slope of Spanish Peak, Plumas County, Cal., are white, coarse-grained dikes composed of corundum and oligoclase.

<sup>1</sup> Geol. Survey Pennsylvania, C<sup>4</sup>, 1883, p. 351.

## CORUNDUM IN CHLORITE-SCHIST.

Besides being associated with chlorites in the peridotites just described, corundum is found in the long belts of chlorite-schist that traverse the country 10 or 12 miles southeast of Webster, Jackson County, N. C. These chlorite rocks, which sometimes attain a width of several hundred feet, are traceable for miles across the country. Almost the only constituent of these rocks is a green scaly chlorite, though sometimes there are present small grains of feldspar, and occasionally needles of amphibole. The chlorite is in small scales, never very coarse, as is sometimes the case in the zones about the peridotite, and often these are so minute as to give the rock a very compact appearance.

In one of these belts, on Caney Fork of Tuckasegee River, Jackson County, N. C., corundum is disseminated through the chlorite in small rounded masses, ranging in thickness from an inch to minute grains, and there the chlorite is not so compact as elsewhere. The corundum is usually wrapped with a white coating of mica, which is a secondary mineral derived from the corundum. The mica is often in radiating scales perpendicular to the outer surface of the corundum, and while in some cases it is very thin, in other cases it has replaced nearly all of the corundum, leaving but a grain of that mineral in the center.

## CORUNDUM IN AMPHIBOLITE.

The occurrence of corundum in amphibolite is important, as the large deposits of emery corundum at Chester, Mass., are found in this rock. Under the head of amphibolite are included all those rocks that are composed entirely or chiefly of amphiboles. These rocks occur rather widely, including, as they do, those of Massachusetts, Georgia, and North Carolina, but with the exception of those that contain the emery they have not, up to the present time, been important in the production of corundum.

Associated with the peridotite rocks of Clay County, N. C., and the adjoining Towns County, Ga., are dikes of amphibolite, which are, for the most part, between the peridotite and the gneiss, although in some places they cut directly across the peridotite formation, but close to the contact of that rock with the gneiss. These dikes vary in width from 25 to over 300 feet, their average width being from 75 to 100 feet. The relation of these amphibolite dikes to the peridotite formation at Buck Creek, Clay County, N. C., is shown in fig. 5.

The groundmass of this amphibolite is a grass-green amphibole, containing 17 per cent of alumina, nearly 12 per cent of lime, and one-half of 1 per cent of magnesia, which is best classified under the edenite variety of aluminous amphiboles. The rich green color of the edenite is undoubtedly due to the presence of a small amount of chromic oxide, the analysis showing the presence of 0.38 per cent of this

oxide. Many microscopic grains of picotite or chromite are scattered through the groundmass of the edenite. There is also present, in widely varying proportions, the plagioclase feldspar anorthite. The feldspar is not constant in all of the amphibolites, and where it does occur it varies in size from minute particles to masses as large as a pea.

The rock has often a very strikingly laminated structure, and grades from that to one which shows no lamination at all. It is exceedingly tough and very fine grained. The corundum, which occurs in the amphibolite as an accessory mineral, varies in size from minute particles to masses several inches in diameter, in which there are usually developed parting planes parallel to the unit rhombohedron. In color it varies from almost white to a deep ruby red, but the prevailing color is a deep pink.

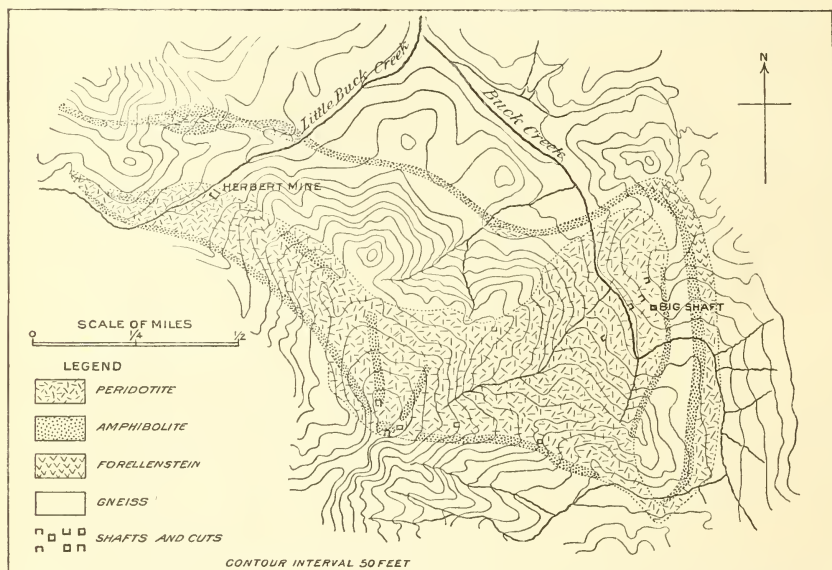


FIG. 5.—Map of the Buck Creek peridotite area, showing the relation of the amphibolite dikes.

On account of the exceeding toughness of the rock, and more particularly on account of the low percentage of corundum, these amphibolites are not of commercial value as a source of corundum; they do, however, make handsome mineral specimens.

On the eastern slope of the Blue Ridge, in the vicinity of Statesville, Iredell County, N. C., corundum has been found associated with an amphibolite composed of a dark-green hornblende. On account of the thickness of the soil and the depth to which these rocks have been decomposed, there are few places where the fresh rocks are exposed, and little is known of their extent. At Hunters, 7 miles west of Statesville, the amphibolite was exposed during

exploration for corundum, which, according to Lewis,<sup>1</sup> was found to occur in fine brown vermiculite, developed in zones along the borders of and penetrating the amphibolite, and varying in thickness from a few inches to 3 or 4 feet. Fig. 6 is an ideal illustration of the occurrence of corundum in the amphibolite at Hunters. In this figure, *a* represents a feldspar vein that is sometimes encountered in the midst of the vermiculites, *b*; the feldspar is more or less altered to kaolin, and often bears corundum, although most of it was found in the vermiculite zones. *b* represents the vermiculite zones carrying the corundum, which is in crystals and in rounded masses of crystals clustered together. Margarite sometimes accompanies it, and large masses made up almost entirely of these two minerals have been found on the surface in this region. *c* represents radiating borders of actinolite that inclose large masses of what was once amphibolite, but which

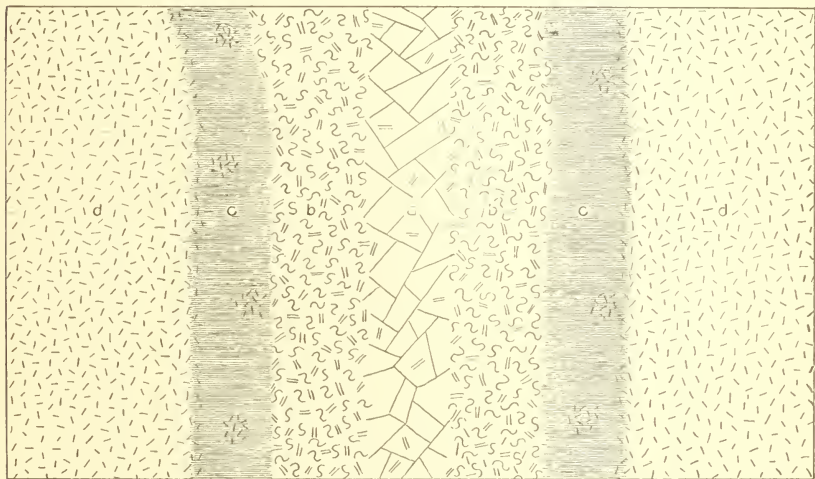


FIG. 6.—Ideal vertical cross section of corundum in amphibolite at Hunters, Iredell County, N. C.

is now nothing but a mass of ochereous clay, bearing occasional needles of hornblende and scales of vermiculite. The outer portions, *d*, are dark-green amphibolite.

#### CORUNDUM (EMERY) IN AMPHIBOLITE AT CHESTER, MASS.

The most widely known occurrence of corundum in amphibolite is that of the emery at Chester, Mass., an elaborate description of which is given by Prof. B. K. Emerson<sup>1</sup> in his exhaustive work on the geology of old Hampshire County, Mass.

Extending almost continuously across the State, north and south of Chester, there is a band of amphibolite that is conformable throughout its entire extent with the sericitic schists of this section of the

<sup>1</sup> Mon. U. S. Geol. Survey Vol. XXIX, 1898.

State. The strike of this band of amphibolite is dependent upon the windings of the schists, and its dip is approximately  $90^{\circ}$ . Its width will average only a few rods, but in the vicinity of Chester, a few miles both north and south of the town, it is three-quarters of a mile wide, and it is in connection with this broad band that the emery is found. It occurs on the eastern side of the amphibolite and is separated from the sericitic schists by a narrow band of amphibolite, varying in width from an inch or two to nearly 18 feet. Sometimes there has been considerable serpentization of the amphibolite, and the emery is separated from the schists by serpentine. Across the Westfield River from the point where the emery is first encountered, the amphibolite is replaced by serpentine, and it is in this bed of serpentine that crystals of this mineral, pseudomorphous after olivine, are said to occur, specimens of these being in the geological collection at Amherst College.

The amphibolite is in appearance a finely laminated rock made up of interrupted thin sheets of feldspar grains and of jet-black needles of hornblende, and usually contains more or less green epidote.

The sericitic schists on the west of the amphibolite, which are described by Professor Emerson under the head of the "Rowe schist,"<sup>1</sup> are biotitic and feldspathic, and often contain garnets that are more or less altered to chlorite. The schists on the east are described as the "Savoy schist,"<sup>2</sup> and are chloritic sericite-schists, mostly of a light-gray color, with a shade of green, due to the chlorite that is mixed with the muscovite. When the chlorite can not be seen with the eye it is readily detected under the microscope. In some places the proportion of the chlorite has increased until there are considerable aggregations of this mineral along the planes of lamination. Garnet and pyrite are also abundant in certain portions of the schist.

The emery vein can be followed for a distance of nearly 5 miles, starting from the point where it is first encountered, at the north end of the broad band of amphibolite, on the left bank of the Westfield River, just above the railroad bridge of the Boston and Albany Railroad. The general strike of the vein is a little east of south and runs for the most part parallel to the line of contact of the amphibolite and schist. Emery is not found throughout the vein, but can be almost continuously followed by means of streaks of chlorite. The vein varies in width from a few feet to 10 or 12 feet, the average width of the emery being about 6 feet. Upon both sides of the emery there are usually developed thin seams of chlorite varying from 1 inch to 6 inches or more in width. During the early history of the mine a seam of feldspar was encountered, about 12 inches wide, lying to the east of the emery and bordered on both sides by chlorite 3 or 4 inches wide. There is also more or less chlorite developed in the mass of the ore body, which varies from some portions that are an almost pure mag-

<sup>1</sup> Mon. U. S. Geol. Survey Vol. XXIX, 1898, p. 76.

<sup>2</sup> Ibid., p. 156.

netite to others where there is an intimate admixture of magnetite and corundum. At the Sackett mine (described on page 68) the corundum, of a bronze color and luster, is coarsely crystallized, giving the ore a porphyritic appearance. Sometimes the corundum has crystallized out in blue and white crystals and in masses of a pound or two in weight.

#### ORIGIN OF THE EMERY.

It is a perplexing question to decide from the examination of this and the surrounding rocks whether the amphibolite is of sedimentary or igneous origin, for there are many indications that point to one and to the other. It is not improbable that some portions of this band of amphibolite, which extends across the State, may have been formed in one way and other portions in the other. Professor Emerson has examined this belt of rocks for practically its entire distance across the State, and while he is inclined to consider this band of amphibolite of sedimentary origin, he does not, if I understand him correctly, see anything antagonistic to the view that at least a portion of this amphibolite is an intrusive igneous rock. I have examined only that portion of the amphibolite adjacent to the emery vein, and from my observations I had come to the conclusion that this part of the amphibolite band was an igneous rock that had been intruded into the schists along their line of weakness, and that the magnetite and emery had been the first minerals to separate out from this magma. The reasons that have led me to this conclusion are given briefly below.

The position of the amphibolite, with a dip of practically  $90^\circ$ , lying between the Rowe and Savoy schists, which would have been a line of least resistance, suggests an igneous origin. What seems to me opposed to the acceptance of a sedimentary origin for this broad band of amphibolite is the separation of the vein of emery and magnetite from the sericitic schist on the east by a band of the amphibolite varying in width from a few feet to 18 feet, which, as far as can be judged superficially, is identical in every way with the amphibolite on the west of the vein. Yet, if the amphibolite and emery are of igneous origin, it would naturally be expected that emery would occur on the west side of the amphibolite, but none has been found there, although it is not certain that it does not occur.

Only a small amount of carbonates has been found in connection with the amphibolite and emery—no more than could readily be accounted for as secondary minerals.

Then, again, chromite has been found in connection with the serpentine that is associated with the amphibolite, some of which is undoubtedly an alteration of this rock. The presence of the chromite in the serpentine is to me a very good indication of its igneous origin, and its being the alteration product of a basic magnesian rock. This,

then, would indicate the existence of former masses of a basic magnesian rock which have been changed into serpentine, the serpentinitization continuing into the amphibolite for some distance.

The emery is not continuous along the strike of the vein, but occurs in a series of pockets in the vein that dip about  $30^{\circ}$  to the north. In going from one pocket to another along the strike there is often nothing to indicate the vein but a small seam of chlorite. The pockets are almost continuous in the direction of the so-called dip and hold this dip very constantly.

It seems to me that this portion of the amphibolite band was an igneous mass intruded after the formation of the sericitic schists, and either after or at the time these schists were tilted to their present position, and that the emery bed is the result of the differentiation of components of the mass that were held in solution by the igneous magma.

The theory that Professor Emerson<sup>1</sup> proposes is also probable, viz:

That the emery-magnetite vein was originally a deposit of limonite which was formed by the replacement of limestone and into which alumina was carried by infiltrating solutions and deposited as allophane and gibbsite. The subsequent metamorphism of the bed, although it may well have been intimately connected with the extremely violent mechanical forces to which the strata have been subjected, was largely completed before these forces had ceased their activity, as is shown by the jointing and brecciation of the magnetite and emery. \* \* \* The less altered ferruginous limestone below was changed into the epidotic amphibolite.

Many points that can be noticed support this conclusion, but these also indicate an igneous origin for the amphibolite. No fresh peridotite rocks have been observed in this section, and the nearest are probably across the Connecticut River at Pelham, where an igneous mass of saxonite is encountered. The presence, however, of chromite in the serpentine associated with this amphibolite is to me very good evidence for believing that the serpentines have an igneous origin, and it is very probable that they are alterations of former masses of an intruded peridotite.

If any deep mining is undertaken on the emery, new evidence may be brought to light that will determine decidedly what may have been the origin of these amphibolites and emery deposits.

#### CORUNDUM IN NORITE.

In the vicinity of Peekskill, Westchester County, N. Y., corundum has been found associated with norites, which have been described by G. H. Williams.<sup>2</sup> These rocks belong to the Cortland series, of which the prevailing rock type is one that is characterized by the presence of the mineral hypersthene. But though this mineral is

<sup>1</sup> Mon. U. S. Geol. Survey Vol. XXIX. p. 145.

<sup>2</sup> Am. Jour. Sci., 3d series, Vol. XXXIII, 1887, pp. 135, 191.

there so abundant, a normal norite, containing nothing but a plagioclase feldspar and hypersthene, is extremely rare. There is more or less biotite, hornblende, or augite developed in nearly all rocks of this class, so that there is a gradual transition from normal norite to mica-diorite, hornblende-diorite, and gabbro. The intermediate varieties are much more common than the extremes, and they have been classified by Williams according to the prevailing nonfeldspathic mineral. Where hypersthene prevails the rocks are grouped as norites, being subdivided into normal norite, hornblende-norite, mica-norite, and augite-norite, according to the presence of these different minerals in the rock. These so grade into each other that no sharp line can be drawn between them.

Associated with the norites, 3 and 4 miles southeast of Peekskill, N. Y., are deposits of magnetite and emery. It is not at all unlikely that these veins are the products of the differentiation of the molten norite magma, by which the basic portion of the magma has been concentrated near its outer surface, a gradual transition occurring toward the center to the more acid norite. This occurrence would be similar to that of the pyrrhotites which have separated out from the norites of Norway, as described by Vogt.<sup>1</sup> In that case the pyrrhotite was concentrated toward the border of the norite, and there is at some places a gradual transition from the pure pyrrhotite through a pyrrhotite-norite to the pure norite, while at others there is a sharp contact between them. The deposits of magnetite and emery are not in a continuous vein, but are more like segregated masses. Attempts have been made to work these for both iron and emery, but as iron-ore deposits they were soon abandoned. They are still being worked to a certain extent for emery by the Jackson Mills Company, of Easton, Pa.; the Tanite Company, of Stroudsburg, Pa.; and H. M. Quinn, of Philadelphia, Pa. An examination of the emery ore by J. D. Dana<sup>2</sup> and G. H. Williams,<sup>3</sup> has shown that the corundum component is often scattered rather sparingly through the ore, and what had formerly been supposed to be green chlorite was found to be the iron-magnesian spinel, pleonaste. The corundum in the emery varies from small, colorless grains to crystals 7 mm. in diameter, which show a hexagonal outline. In other parts of the emery the corundum grains are larger and of a bluish color.

The pleonaste, which is so commonly associated with the emery, has been found at the Cruger iron mine, in the eastern part of the township, as veins in a nearly normal norite, into which it passes by gradual transitions. The most compact specimens of the ore at this mine are found to contain the various mineral components of the norite, i. e., hypersthene feldspar, biotite, and garnet, no corundum having been observed here.

<sup>1</sup> Zeitschr. für Prakt. Geol., Nos. 1, 4, and 7, 1893.

<sup>2</sup> Am. Jour. Sci., 3d series, Vol. XX, 1880, p. 199.

<sup>3</sup> Idem, Vol. XXXIII, 1887, p. 194.

This gradual transition of the pleonaste and iron ore into the normal norite and the occurrence of the norite minerals in the compact ore are strong evidence that these ore bodies were formed by the differentiation of the molten norite magma.

In the vicinity of these norites there are small masses of peridotite, but no corundum has been found associated with them.

#### CORUNDUM IN BASIC MINETTE.

Near the entrance of Yogo Gulch, in Fergus County, Mont., two parallel dikes of igneous rock have been observed cutting through the limestones. These dikes are about 800 feet apart, and can be followed for over a mile in a nearly east-west course. Their general width is from 6 to 20 feet, but they are occasionally 75 feet wide. They are much decomposed near the surface, but in working them for the sapphires which they contain the nearly unaltered rock has been encountered.

The rock has a dark-gray, decided basic appearance, and is very tough, breaking with an uneven fracture. Scattered through it are light-green and white fragments, which are by far the most conspicuous of any of the mineral components of the rock. These are a pyroxene that is more or less decomposed and calcite. Some of these white fragments are probably the barium carbonate witherite, for in the concentrates obtained from washing the decomposed portions of the dike a considerable quantity of this mineral was found. Numberless crystals of pyrite, not over a millimeter in diameter and almost perfect trapezohedrons, were also found in these concentrates. A few scattered tablets of biotite, from 2 to 3 mm. in diameter, were observed. The sapphire variety of corundum is found rather sparingly in this rock in well-formed, flat, tabular crystals, some of which are half an inch in diameter.

Professor Pirsson, of the Sheffield Scientific School, has made a petrographical examination of this rock, and describes it as follows:<sup>1</sup>

In the section the rock at once shows its character as a dark, basic lamprophyre, consisting mainly of biotite and pyroxene. There is a little iron ore present, but its amount is small and much less than is usually seen in rocks of this class. The biotite is strongly pleochroic, varying between an almost colorless and a strong, clear, brown tint. It occurs in ragged masses, rarely showing crystal outline, and it contains a large amount of small apatite crystals. The pyroxene is of a pale-green tint, with the habit of diopside, and is filled with many inclusions, now altered, but probably originally of glass; in some crystals these inclusions are so abundant as to render the mineral quite spongy. The grains sometimes show crystal form, but are mostly anhedral and vary in size, though the evidence is not sufficient to show two distinct generations.

These two minerals lie closely crowded together, and no feldspars are seen in the rock. The interstices between them consist of a small amount of a clouded, brownish, kaolin-like aggregate, which appears to represent some former feldspathoid

<sup>1</sup> Am. Jour. Sci., 4th series, Vol. IV, 1897, p. 421.

component, possibly leucite, perhaps analcite. \* \* \* Some calcite in agglomerated granules is also seen in the section.

This calcite does not appear to be of secondary origin, and is probably due to fragments of limestone that were picked up as the igneous mass forced its way up through the limestones and were converted into calcite.

As has been indicated by Professor Pirsson<sup>1</sup> in his paper, the amount of biotite in this rock shows that it is closely related to the minettes, and although it is lacking in feldspar it has the biotite and pyroxene of these rocks. It is a more basic type of these and is also similar to the shonkinites from the Highwood Mountains, Montana, described by Weed and Pirsson.<sup>2</sup>

The sapphires, which are all of some shade of blue, occur but rarely in the rock, and from their sharp, distinct crystals and their general distribution it is very evident that they have crystallized out of the molten magma at the time of its intrusion, similarly to crystals of feldspar in porphyry. The alumina of the sapphires was not an original constituent of the magma, but, as has been shown by Pirsson,<sup>3</sup> was due to inclusions of clay sediments taken up from the strata through which it passed. The Belt formation, consisting of clay shales of great but unknown thickness, undoubtedly underlies the limestones, and the included fragments of these shales were the source of the alumina of the sapphires. These included fragments would be dissolved by the molten magma and thus form local areas that would be very rich in alumina. As the magma began to cool corundum crystals would separate out in these alumina-rich areas.

#### CORUNDUM IN ANDESITE.

The occurrence of corundum in andesite in the United States was first described by Kunz.<sup>4</sup> He described a dike of andesite at Ruby Bar, near Eldorado Bar, on the Missouri River, 12 miles northeast of Helena, Mont. As described by him, this rock is in a dike cutting the slates of the country and is a vesicular mica-augite-andesite, which is made up of a groundmass of feldspar microlite and a brownish glass, in which are many particles of biotite and crystals of augite.

A similar occurrence has been observed by myself on the river 6 miles above Eldorado Bar, at French Bar, which is nearly 12 miles due east of Helena. At this locality a narrow dike, 3 to 6 feet wide, was found cutting through the slates of this section. The trend of the dike is N. 5° to 10° E., and it dips about 45° E. It was encountered by miners who were working the gravels of the bar for sapphires, and it has been exposed at but one point, so that its extent is not known.

<sup>1</sup> Am. Jour. Sci., 4th series, Vol. IV, 1897, p. 422.

<sup>2</sup> Idem, Vol. I, 1895, p. 467.

<sup>3</sup> Idem, Vol. IV, 1897, p. 423.

<sup>4</sup> Idem, Vol. IV, 1897, p. 418; Min. Mag., Vol. IX, 1891, p. 396; Seventeenth, Eighteenth, Nineteenth, Twentieth Ann. Repts. U. S. Geol. Survey.

The rock is fine grained, of a rather light-gray color, and a decided basic appearance. Biotite is the most conspicuous mineral and occurs in small, flat, tabular plates, sometimes with distinct crystal outline, and up to a millimeter or two in diameter. In some specimens of the rock there are nodules, 5 to 10 mm. in diameter, that appear to be partially decomposed feldspar. The augite, which is prominent in the thin section, is not very apparent in the hand specimen.

Prof. L. V. Pirsson, of Yale University, has kindly examined thin sections of this rock for me and says that the rock is an altered augite-mica-syenite. It contains unaltered phenocrysts of a clear brown biotite which are well crystallized and which sometimes show slight resorption. It also contains phenocrysts of augite of a pale-brown color, variable in size, the largest 2 mm. across, replaced in the majority of cases by pseudomorphs of calcite. Besides this pseudomorphous calcite there is also a considerable amount of this mineral in irregular masses or streaks, which may in part be the filling of steam pores and in part be pseudomorphous after hornblende; this, however, could not be definitely determined. The minerals just mentioned are embedded in a groundmass of a brown glass which is everywhere speckled and dotted with microlites of a lath-shaped plagioclase feldspar. These are small and somewhat altered, so that their determination is not entirely satisfactory, but they appear to be oligoclase.

The rock is thus porphyritic, and the structure of the groundmass is typical for the hyalopilitic structure of Rosenbusch. In many respects it closely resembles the augite-porphyrityte of Weiselberg, weiselbergite.<sup>1</sup>

One feature that is brought out in the thin sections is the somewhat laminated character of the rock in one direction, while in the slide cut at right angles to this a well-characterized flow structure is observed, all the longer axes of the minerals pointing in one direction. This indicates movements of flowing lava after the components had formed.

The corundum crystals occur very sparingly in the rock, and those that were observed were not so sharp and distinct as the blue sapphires.

I could obtain no definite information regarding the location of Ruby Bar and no one of the bars is now called by that name. It is possible that the bar described by Kunz is the same as the one now known as French Bar. From the description given of Ruby Bar, it is apparently not so far up the river as French Bar.

#### CORUNDUM IN SYENITE.

On a high foothill between Gallatin and Madison rivers, in Gallatin County, Mont., corundum has been found in a rock that is

<sup>1</sup> Rosenbusch, *Mass. Gest.*, 3d ed., p. 953.

composed essentially of orthoclase feldspar, corundum, and biotite, with the feldspar predominating. This would classify the rock as a corundum-bearing biotite-syenite. The rock, for the most part, has a somewhat gneissoid structure, and in these portions the corundum is more or less finely divided, being in fine grains and small crystals. In other portions, where the corundum is coarsely crystallized, the rock has something of a pegmatitic character, and the corundum is surrounded by the orthoclase. The crystals of corundum vary in size; the largest ones are  $1\frac{1}{2}$  inches long and from a quarter to a half an inch in diameter. They are fairly well developed in the prismatic zone, but many of them, especially the larger ones, are rounded. In color they vary from bluish gray to almost colorless. The percentage of the corundum in the rock is large, and from a superficial examination it could be compared to the percentage of quartz in an average granite. The biotite is in small tablets, without definite crystal outline, and the tablets are often so arranged as to give the mass of the rock its gneissic appearance. The orthoclase did not show any crystal outline even in the larger fragments.

This occurrence of corundum was discovered by Prof. F. W. Traphagen, of Bozeman, Mont., to whom I am indebted for the specimens.

From the appearance of the hand specimens, this occurrence of corundum is similar to that in the syenite of Ontario, Canada, recently described by Blue<sup>1</sup> and Miller.<sup>2</sup>

#### CORUNDUM IN AMPHIBOLE-SCHIST.

At the Sheffield mine, in Cowee Township, Macon County, N. C., corundum has been mined in a saprolitic rock at various times for a number of years. In a shaft sunk to determine the depth of the corundum-bearing saprolite, solid, unaltered rock was encountered. The shaft, which was 87 feet deep, passed through the following rocks: The first 12 feet (*a*) was through the saprolite, in which there were seams of kaolin; the next 2 feet (*b*) were corundum bearing. From 14 to 28 feet (*c*) the same saprolite was encountered; the next 2 feet (*d*) were corundum bearing, followed by 10 feet (*e*, 30 to 40 feet) of the saprolite, and 2 more feet (*f*) that were corundum bearing. From 42 to 63 feet (*g*) the rock began to be less decomposed, and from 63 to 66 feet (*h*) another seam of corundum-bearing rock was encountered. From this point to the bottom of the shaft the rock became more and more solid, until at 77 feet (*i*) the fresh rock was encountered. These various seams in the rock are very pronounced. They dip  $30^\circ$  toward the west near the top, but become nearly horizontal near the bottom

<sup>1</sup> Trans. Am. Inst. Min. Eng., Vol. XXVIII, 1898, p. 565, and Rept. Bureau of Mines, Ontario, Vol. VIII, Part II, 1899, p. 240.

<sup>2</sup> Rept. Bureau of Mines, Ontario, Vol. VII, Part III, 1898, p. 238, and Vol. VIII, Part II, 1899, p. 205.

of the shaft. The seams of decomposed feldspar observed in *a* become less and less kaolinized, until in *i* the seams are of pure plagioclase feldspar. In *i* there are two seams of corundum similar to *b*, *d*, and *f*, although in the fresh rock the corundum seams are not as pronounced as in the saprolitic rock. There is often a considerable amount of feldspar bordering the seams of the corundum. The general trend of the rock is about N. 5° to 10° E.

From what could be seen of the solid and the saprolitic rocks, it is evident that the corundum occurs at intervals in the rock in seams a few feet in width. While the corundum may comprise 10 per cent or more of these veins, the amount in the rock that it would be necessary to mine would probably not be over a few per cent. The actual width of the dike is not known, but the saprolitic rock has been cut across for about 100 feet in a direction nearly at right angles to its strike.

The fresh rock at the bottom of the shaft is somewhat varied in appearance, and while it does not show any definite gneissoid structure, it sometimes closely resembles it. There are streaks in the rock a few inches thick, the more finely divided portions of which are distinctly gneissoid.

Some portions of the rock are decidedly porphyritic, and contain phenocrysts of a light-gray amphibole, a centimeter in diameter, in a groundmass of feldspar. A large part of the rock is made up, however, of small, roughly outlined prismatic crystals of an amphibole, probably hornblende, and irregular fragments of plagioclase feldspar. The hornblende is almost black in color, but in thin splinters it has a bronze luster and a deep resinous color. Biotite of a deep-brown color occurs sparingly, and a pink garnet is rather abundant. This part of the rock has a gneissoid structure and contains the corundum. The corundum is of a light to a purplish-pink color and occurs in nodules up to 2 or 3 cm. in diameter. Some streaks in the rock are highly garnetiferous, composed essentially of the garnet and plagioclase feldspar or of garnet and biotite. Chalcopyrite occurs very sparingly in these portions of the rock. Small particles of graphite have been observed in the coarsely crystallized portions.

Professor Pirsson has kindly made a microscopical examination of this rock, the results of which are embodied in the following paragraphs:

In thin section the microscope disclosed the minerals hornblende, plagioclase feldspar, garnet, biotite, muscovite, staurolite, and rutile. Hornblende is the most common, forming about two-fifths of the section, while of the remainder plagioclase and garnet occur in about equal quantities and the others in comparatively insignificant amounts.

The hornblende is formless, but tends to irregular columns, almost invariably extended in the plane of schistosity. It has very rarely a somewhat stringy tendency in its cleavage, but is usually homogeneous in broad plates. Its color is a clear olive brown, and it is somewhat pleochroic, but not strongly so. It is every-

where dotted by the small grains of garnet, which rarely show good crystal form. The garnet occurs associated also with the plagioclase.

The plagioclase occurs twinned according to the albite law only. In sections perpendicular to 010 the lamellæ show extinction as great as  $30^\circ$ , and the plagioclase is therefore rich in lime and as basic as labradorite, which it probably is. It shows strong evidence of shearing movement in the rock; it is often broken, exhibits rolling extinction, and the albite lamellæ are curved and bent. It runs along the planes of schistosity between the feldspars and forms a mosaic of angular broken grains.

Staurolite was found in rather broad, irregular grains, and rutile in small, irregular grains and well-crystallized prisms.

Professor Pirsson has indicated that the character and structure of this rock, composed chiefly of amphibole, labradorite, and garnet, suggest most strongly that it is a metamorphosed igneous rock of the gabbroid family. During metamorphism the augite of the gabbro would be converted into the brown hornblende; any iron ore that was present would be taken up by the hornblende and garnet. The rutile would have resulted from the titanitic acid that is a regular component of the iron ores in these gabbro or diabase rocks. Staurolite is a mineral that would be rather naturally expected, as it is usually a mineral of metamorphism, and its natural home is in the schistose rocks. The feldspar has suffered the least (except the corundum) chemically, and shows only the shearing of dynamic processes.

The corundum does not occur in crystals, but in small fragments and in elongated nodules, which are cracked and seamed and appear to have been drawn out by the shearing processes. The general character and shape of the fragments of corundum would indicate that they were original constituents of the igneous rock and were not formed during its metamorphism.

The exact classification of this rock is not easy, but it is probably an amphibole-schist.

#### CORUNDUM IN GNEISS.

Corundum has been found in North Carolina in the ordinary gneiss of the same belt of crystalline rocks in which the peridotites occur. A number of occurrences, part of which may be corundum in gneiss, are described under the head of mica-schist; some of the rock that was at first thought to be a gneiss is now known to be a quartz-schist.

In the eastern part of Clay County, N. C., on the southern slope of Gross Ridge of the Chunky Gal Mountains, just above Thumping Creek, corundum has been found in the gneiss at a number of points. The rocks are so covered with soil and decomposed rock that the exact relation of the corundum-bearing gneiss to the normal gneiss can not be determined, but from what can be seen the former appears to be in narrow bands cutting through the latter. In structure the gneiss is distinctly laminated and very fine grained, except the portions immediately surrounding the corundum, where its constituents

are much more coarsely crystallized, especially the biotite. It is a hornblende-gneiss, showing but little mica except where associated with the corundum.

The corundum occurs in nodules and crystals, half an inch and smaller in diameter, sometimes wrapped with muscovite in a manner similar to that described for the corundum in the chlorite-schists (p. 21). The crystals are prismatic, with the length of the prism usually two or three times its diameter. Occasionally they are very flat, with the prism not over a quarter of an inch in length and half an inch in diameter, and from their appearance these crystals are known locally as "button" corundum.

This occurrence of corundum in gneiss is in no way associated with the peridotite rocks of this section of the country. It is, however, very similar to the occurrence of corundum in quartz-schist described below. None of the peridotite rocks in which the corundum is so commonly found in this section of North Carolina have been found associated with these bands of gneiss.

#### CORUNDUM IN MICA-SCHIST.

It has recently been observed that portions or bands of the crystalline rocks of the southwestern part of North Carolina and the north-eastern part of Georgia are corundum bearing. The composition of these rocks varies from those that are a normal gneiss to those that contain no feldspar and can best be described as quartz-schist composed of biotite, mica, and quartz. Some portions of the rock are rich in garnet, others are almost entirely free from this mineral, and occasionally there are also small bands of white quartzite. The rocks are distinctly laminated and are frequently intersected by granitic dikes, some of which are coarsely crystallized and of a pegmatitic character. These dikes are often parallel with the bedding of the schists, although many of them cut irregularly through them. Where these dikes are parallel to the bedding of the schists, the laminated structure of the latter is much more apparent. The general strike of these crystalline rocks is about northeast to southwest and the dip is about 30° NW.

Portions or bands of these schists are corundum bearing, but they are irregularly defined and gradually merge into the normal rock. They have a similar relation to the normal schists as the garnet-bearing bands of a gneiss to the normal gneiss in which they occur. These bands are not veins in any sense of the word, but are simply portions of the same mass of crystalline rocks in which corundum occurs as a constituent of the rock. They vary in width from a foot or two to 12 or 15 feet, but in these wider ones the corundum-bearing portion is not continuous and is intercepted by streaks of barren rock and granitic dikes. The bands can be traced for a distance of 5 or 6 miles in a northeast-southwest direction, sometimes outcropping

continuously for nearly a mile. There are at least two of these corundum-bearing bands which are parallel to each other and about 2 miles apart. The only variation that has been observed in them is in the percentage of corundum and garnet; otherwise they are identical. The amount of corundum is never large, and from determinations made on samples from various parts of the deposits it will not average over 4 or 5 per cent.

The corundum occurs for the most part in small particles and fragments that have no regular shape and are of a gray, white, and bluish-white color or almost colorless. It is also in crystals which vary in size from some that are very minute to some that are  $2\frac{1}{2}$  inches long and about one-half inch in diameter, and which are usually fairly well developed in the prism zone.

It is probable that these schists are the result of the metamorphism of sandstones and shales formed from alluvial deposits many thousand feet in thickness that were once the bed of the ocean. By lateral compression these have been folded and raised into the mountain ranges of this region. That these have been much higher than at the present time is very evident from the granitic dikes, which are of deep-seated origin. By decomposition and erosion the mountains have been worn down to their present condition, thus exposing the schists in contact with the granitic dikes which have aided in their thorough metamorphism. The shales were rich in alumina, and during their metamorphism the excess of the alumina crystallized as corundum along the planes of lamination, so that during the subsequent weathering the corundum has been left in knotty nodules, studing the surface of the rock and giving it the appearance of containing a high percentage of the mineral.

Genth<sup>1</sup> has described an occurrence of corundum in Patrick County, Va., about 2 miles from Stuart, where it has been found in the mica-schists on a knob of Bull Mountain. These schists are talcose and chloritic in character and are intersected by a number of granitic dikes. The portions of the schists in which the corundum occurs are gneissoid in character. This occurrence is decidedly different from that in Clay County, N. C., and more like the corundum-bearing schists near the headwaters of Caney Fork of Tuckasegee River, in Jackson County. The schists are in rather narrow bands that can be followed for some distance across the county. They are not true chlorite-schists like those described on page 21, but are made up largely of an elastic mica (probably muscovite) with some chlorite. The corundum occurs in rough crystals and nodules up to 1 inch in length and half an inch in diameter, of a grayish-white to white color and colorless. It is readily cleaned, and tests made upon the cleaned product show that it is well adapted for the manufacture of the vitrified wheel.

<sup>1</sup> Am. Jour. Sci., 3d series, Vol. XXXIX, 1890, p. 47.

CORUNDUM IN LIMESTONE.<sup>1</sup>

Extending from Byram, Sussex County, N. J., to Warwick Township, New York, a distance of about 25 miles, there is a belt of limestone having a general northeast-southwest strike, which widens out toward its northern end. About 1828 a specimen of sapphire corundum was found at Franklin Furnace in a detached piece of rock composed essentially of feldspar, and although search was made no more specimens were found in this vicinity. A few years later sapphire corundum was found in Newton Township, about 6 miles from Franklin Furnace, embedded in a feldspar and partly surrounded by a carbonate. This occurs near the contact of the limestone with the granitic rocks of this section, and it is very evidently the result of contact metamorphism. Dana reports the occurrence of sapphire corundum in these limestones near Newton and Vernon, Sussex County, N. J., and near Amity, Orange County, and Crugers Station, Westchester County, N. Y.

Prof. W. P. Blake<sup>2</sup> has described the occurrence of red sapphire corundum in the white crystalline limestones in Vernon Township, Sussex County, N. J. The finest specimens were ruby red in color and the others were of various shades of purple. The crystals were translucent, but no transparent ones were observed. They were embedded in the limestone and it is not improbable that crystals may occur in the similar rocks of the adjoining counties of New York.

The New Jersey occurrences seem to be well authenticated, but those from New York are not. In the report of the New York State Museum for 1895 on the mineral resources of the State there is no mention of the occurrence of corundum at this locality, and in the report for 1898 it is stated that no sapphire corundum is found in the State.

## CORUNDUM IN CYANITE.

The occurrences of corundum associated with cyanite are quite widespread, and at times there are large masses of cyanite in which are numerous hexagonal crystals of corundum. At Litchfield, Conn.,<sup>3</sup> a mass of cyanite containing crystals of a dark, grayish-blue corundum, which was said to have weighed 1,500 pounds, was found. Large masses of cyanite have been found at various points in North Carolina in which there were well-developed crystals of corundum.

All the occurrences that have been noted have been from surface specimens, and the rocks in the vicinity have always been either schists or gneisses. It is without doubt in connection with these rocks that the cyanite and corundum originated. I do not believe that the cyanite is usually an alteration product of the corundum, as has been sug-

<sup>1</sup> Am. Jour. Sci., 1st series, Vol. XXI, 1832, p. 319.

<sup>2</sup> Idem, 2d series, Vol. XIII, 1852, p. 116.

<sup>3</sup> Idem, 1st series, Vol. VI, 1823, p. 219.

gested by Genth,<sup>1</sup> but that they were both formed during the metamorphism of the rocks from which the schists and gneisses have been derived.

#### SUMMARY OF CORUNDUM OCCURRENCES.

From the facts presented in the preceding pages, the occurrences of corundum are seen to be of much greater variety than was formerly supposed. While the large concentrated masses are still confined to the basic magnesian rocks, corundum is scattered in small amounts through a number of other rocks, and in the aggregate is in very large quantity.

Of the igneous magmas there are two that are very distinct from each other and that can be designated as the lime-magnesia and the alkaline series. In the first the mineral components of the rock are free from alumina, and where there has been alumina in solution in the molten magma it has all separated out either as corundum or spinel. In the second series, however, it is only the excess of alumina that has separated out as corundum, by far the larger percentage having united with the alkaline oxides to form a feldspar. In all the occurrences that have been examined this phenomenon has been constant.

It is very evident that there are magmas that contain an excess of alumina just as there are magmas with an excess of silica, and it is evident that the alumina separates out as corundum in the same manner that silica separates as quartz in granitic rocks.

#### DISTRIBUTION OF CORUNDUM.

Most of the corundum that has been mined for abrasive purposes has been obtained from the eastern part of the United States, and has been found associated with the long belt of basic magnesian rocks extending from Massachusetts to Alabama. It is in the southern portion of this belt, in North Carolina and Georgia, that these rocks have their greatest extent, and it is in this region that the greatest quantity of corundum has been found. During the past few years, however, North Carolina is the only State that has produced any corundum and Massachusetts and New York the only ones that have produced any emery.

While the production of corundum has been limited almost entirely to one locality in North Carolina, it is not because this is the only known deposit of this mineral in quantity, but because the better deposits have not been worked. The emery deposit that has proved of the most economic importance, and which has produced practically all the emery mined in the United States, is at Chester, Mass. The amount of corundum that has been mined during the past year is very much less than the amount of emery, although its market value

<sup>1</sup>Am. Philos. Soc., Vol. XIII, 1873, p. 22.

is twice that of the emery and there is a large demand for a well-cleaned commercial product. There are a number of reasons for this condition: the better deposits have been so controlled and tied up that they could not be worked, an imperfectly cleaned product has been put on the market, and other minerals have been substituted for this one.

It is still too soon to predict to what extent recent discoveries of corundum in Canada and India will add to its production. Some of the Canadian deposits in Ontario were granted by the government to the Canada Corundum Company, Limited, of Toronto, and this company began extensive operations on the deposits at the beginning of 1900. This corundum, which occurs in a syenite similar to that described on page 30, has been thoroughly tested and has given fairly satisfactory results. The reports of the bureau of mines at Toronto show that this ore carries 14.7 per cent of corundum and that a very clean product is obtained. If the ore from this extensive Canadian bed continues to carry so large a percentage of the mineral, can be readily cleaned, and shows good abrasive qualities, this deposit should play an important part in the world's production of corundum (see page 88).

The India corundum occurs at Pipra, South Rewah. It is pink in color, with a fine-grained massive structure, and very tough. It is reported that there is an unlimited supply of this material, and it has already been used in this country in the manufacture of certain oilstones (see page 89).

In the following descriptions of localities those that contain sapphires are first taken up, then the corundum, and last the emery.

#### SAPPHIRE OR CORUNDUM GEMS.

The properties of a mineral that determine its rank as a gem are hardness, color, rarity, index of refraction, and luster. As an illustration of the extent to which the hardness affects the value of a mineral for gem purposes, sphalerite might be cited. This mineral, which has an index of refraction and a luster not far below that of the diamond, has a hardness of only 3.5 to 4, which effectually cuts it off from being a gem mineral.

Corundum has properties that place some of its varieties among the most valuable gems. With the exception of the diamond, it is the hardest mineral known, and the rarity and color of the ruby, the red corundum, has made that gem, when more than a carat in weight, more valuable than a diamond of corresponding weight. Corundum has been found in almost all the colors of the rainbow, and in the following list its gems have been classified according to color. They are very often designated by the prefix "oriental," to distinguish them from gems of the same name whose mineral composition and character are entirely different.

*Sapphire or corundum gems.*

Oriental or true ruby.....	Red of various shades.
Oriental sapphire.....	Blue of various shades.
Pink sapphire.....	Rose or pink.
White sapphire.....	{ Colorless.
Diamond spar.....	
Opaline.....	{ Pale blue or bluish white.
Girasol.....	
Hyaline.....	
Oriental amethyst.....	Purple.
Oriental emerald.....	Green.
Oriental topaz.....	Yellow.
Star sapphire.....	{ Opalescent.
Chatoyant.....	
Asteria.....	

The gems occur in the mines in three forms: First, as crystals, of which there are two distinct forms, (1) hexagonal prisms terminated by rhombohedrons and pyramids, sometimes with basal plane, the larger crystals being often rounded or barrel-shaped, and (2) flat, tabular crystals, where the basal plane is very largely developed; second, as transparent colored portions of larger massive pieces of corundum; third, as nodules of finer and clearer material in a mass of cleavable corundum, often having the appearance of rolled pebbles when separated from the mass of corundum.

## ORIENTAL RUBY.

The most important of the sapphire gems is the oriental ruby, which varies from rose, pinkish, dark-red, and purplish to pigeon-blood color, the most highly prized. The rubies are very likely to be flawed, and when examined many of the cut stones are found to contain flaws of one character or another. The stones are often so cut that these flaws are distinguishable only by the aid of a magnifying glass.

The finest rubies of pigeon-blood color are those found in the Mogok district, about 90 miles north-northeast of Mandalay, in upper Burma. Small but fine rubies, often, however, of a pink color or a purplish tint, are found at Ratnapoora, in Ceylon, and of a dark-red color, similar to that of a garnet, in Siam. The rubies of the Burma district are found in situ in limestones, but the mining is confined almost entirely to the gravels.

At the Corundum Hill mine, Cullasagee, N. C. (see description, page 55), various shades of gem ruby corundum have been found. Two of the best rubies of good color that have ever been found at this mine are in the collection of Clarence S. Bement, of Philadelphia; there are also a number of fine ones in the United States National Museum at Washington. Many of the smaller crystals of various shades of pink to red are transparent near the outer surface and near their extremities, and from these small gems can be cut, but

few that are worth \$100 have been obtained from them. These smaller crystals are usually well developed and have a clean-cut form. The faces commonly developed on these are the base,  $c$ , 0001; the unit prism,  $m$ ,  $10\bar{1}0$ ; the unit rhombohedron,  $r$ ,  $10\bar{1}1$ , and the pyramid,  $u$ ,  $22\bar{4}3$ , more rarely observed.

The North Carolina locality for corundum gems which at the present time is attracting the most attention is the tract of land between the Caler Fork of Cowee Creek and Mason Branch, tributaries of the Little Tennessee River.<sup>1</sup> This tract is situated in Macon County, almost 6 miles below (north of) the town of Franklin. The nearest railroad station is Dillsboro, Jackson County, on the Southern Railway, about 12 miles to the east. The bottom of the valleys are about 2,500 feet above sea level, and the mountain peaks or knobs in the immediate vicinity rise to a height of 3,000 or 3,500 feet.

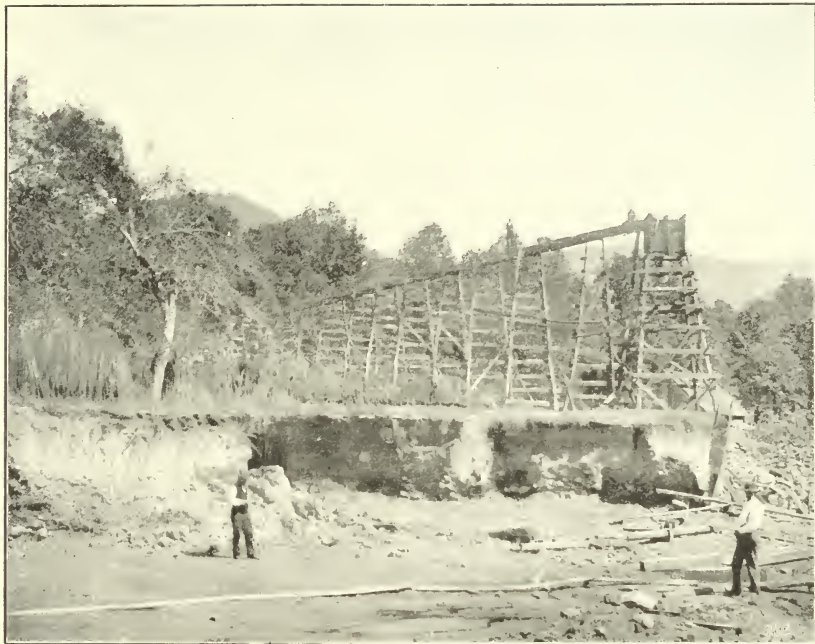
In the gravels of Caler Fork Valley pieces of crystals of red corundum were picked up by the people of the district, which led to the driving of two or three tunnels with the expectation of striking the vein and finding the corundum in sufficient quantity for commercial purposes. Work in this direction was soon abandoned, and for a number of years there were only prospecting and a little mining for the red corundum for gem purposes.

Systematic search was made, which revealed the fact that ruby corundum was to be found in the gravels of Caler Fork Valley for a distance of 3 miles. In 1895 the American Prospecting and Mining Company, of New York, bought out the old claims and began work on a systematic basis. The property owned by the company is a large tract on both sides of Caler Fork of Cowee Creek and nearly all the land in the northern part of the watershed of Mason Branch, a total area of about 5,000 acres.

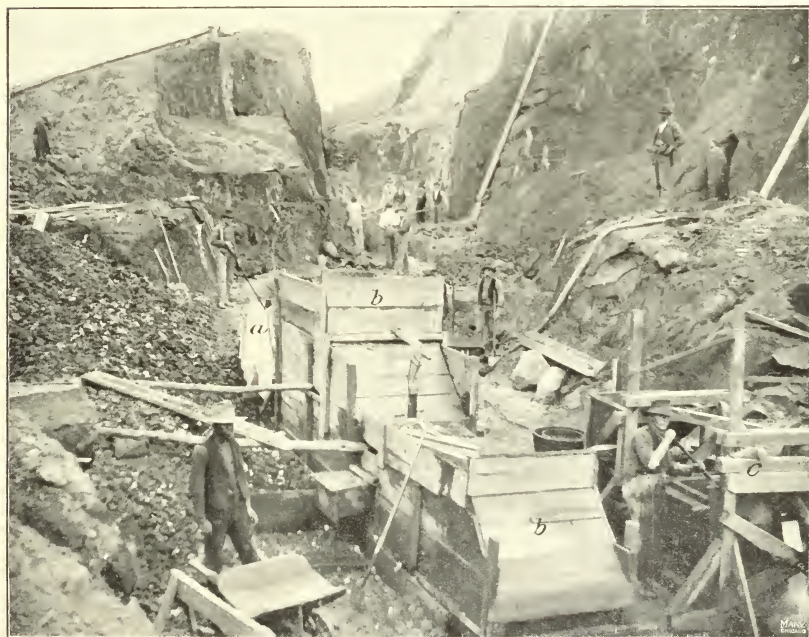
The gravels in which most of the rubies have been found are covered by soil averaging about 2 feet in depth, but varying from 1 to 5, and they are about 3 feet higher than the present alluvial gravel of the stream. Pl. II, *A*, is a view of one of the gravel beds that is being worked for rubies, just west of the company's office. The gravel in this part of the valley, which is overlain with 3 to 5 feet of soil, is composed of waterworn masses of quartz and small pebbles of gneiss and quartz, and is much cleaner in appearance than the gravels a mile farther up the creek, at In Situ Hill, where most of the mining was carried on during 1898. Fifty feet above the level of this gravel another bed was discovered at In Situ Hill which carried ruby corundum.

In washing these gravels for the rubies, hydraulic processes have been used very similar to those used in the West in washing gold-bearing gravels. All the soil, as well as the gravel, is washed into a short line of sluice boxes (*a* of Pl. II, *B*) which lead into a large sieve

<sup>1</sup>Am. Jour. Sci., 4th series, Vol. VIII, 1899, p. 370.



1. BED OF RUBY-BEARING GRAVEL AT CALER FORK, COWEE VALLEY, MACON COUNTY, N. C.



RUBY MINE AT COWEE VALLEY, N. C.

Plant for washing the gravels is shown in the foreground; *a*, sluice box; *b*, sieve boxes; *c*, rocker.



box (*b* of Pl. II, *B*), where the large pieces of rock and bowlders are removed and most of the dirt and fine gravel is washed out. They are then shoveled into a rocker (*c* of Pl. II, *B*), where they are further cleaned and concentrated, the final concentration of the rubies being done by hand.

No basic magnesian rocks or serpentine derived from them, in which most of the corundum of North Carolina occurs, have been found in this valley. Corundum Hill and the Ellijay corundum region are, however, less than 10 miles to the south.

Although, in many respects, the occurrence of the rubies and their associate minerals in the Cowee Valley is similar to the occurrence of the ruby in Burma, no limestone has been found near the alluvial deposits, the nearest point at which limestone has been found being at Cullowee Gap, about 8 miles to the southeast.

The country rock of the district is a gneiss, of a gray, fine-grained variety, which has a great many small garnets disseminated through it. The rock for the most part is in a highly decomposed condition, but there are small exposures of the undecomposed rock in many places. The gravels in which the rubies are found rest on a soft rock known as saprolite, which is the result of weathering of the basic silicate rocks in place. By means of shafts and the workings at the gravel washings it has been shown that at a depth of 35 feet or more these saprolitic rocks contain fragments of the undecomposed rock and pass into such rocks as eclogite-amphibolite and a hornblendic gneiss.

A narrow dike of hornblendic eclogite a few feet in width is exposed near the present workings of the company and can be traced for about 100 yards.

No rubies have been found in the undecomposed rock, but at In Situ Hill small rubies of a rather pale color were found in a narrow band of saprolitic rock. This band was, however, cut off by slickensides so that it could not be followed in any direction. There are four parallel slickensides that have been exposed at one place in the workings, the general direction of the slides being N. 75° E. Some of these are 70 feet in length and of unknown depth. It is very evident that there has been a great deal of disturbance in this immediate vicinity through the breaking of the rock masses by faulting, the ready influx of water having caused the reduction of the rocks to their saprolitic condition.

In washing the gravels and masses of saprolite, masses of undecomposed rock have been uncovered, and in the center of these nodules of the pure hornblende rock have been found. The saprolite bordering these nodules often contains particles and crystals of corundum.

Less than 2 miles to the east of In Situ Hill, beyond Betts Gap of the Cowee Mountains, corundum of a gray to bluish color, but highly

crystallized, has been found in hornblende-gneiss. One mile a little north of west, at the Sheffield mine, pink corundum has been found in amphibole-schist (see pages 31 and 58).

An association of corundum peculiar to this locality is with the garnet, rhodolite. Corundum and garnet occur not only constantly together in the saprolitic material and in the gravels, but corundum crystals have been found that bear the impression of the garnet. By means of wax a mold was taken of these impressions, and they were shown to be either the dodecahedron or trapezohedron. Then again some of the ruby crystals when broken are seen to have a garnet inclosed, and the garnet can often be seen in the transparent ruby crystal and the cut gem.

As has been said, there is no limestone in this immediate vicinity and these rubies were probably derived from an amphibolite or eclogite. The usual flat tabular form of the crystals is one that seems to be characteristic of the gem corundum when found in igneous rocks.

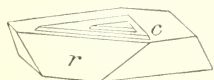
The Cowee Creek rubies frequently contain inclusions, some of which are very minute, known to jewelers as "silk," and these give rise to a cloudiness or sheen in the polished gem. Rutile and menaccanite often occur in the rubies and greatly mar their beauty and value. Some gems that were 3 or 4 carats in weight have been cut, which were free from inclusions, of fine color, and transparent. A great many smaller ones have been cut that are perfect gems. In color and brilliancy these gems are equal to the Burma ruby, and if the percentage of the unflawed transparent material increases but little this new field will be a worthy rival to the Burma field.

A considerable percentage of the transparent material is often very badly flawed by cracks due to parting, and by the inclusions of rutile or menaccanite, so that the percentage of perfect stone from this mine is small. This, however, is true of the rubies from the Burma field, for a large proportion of the rubies on the market to-day are usually more or less flawed with the parting cracks.

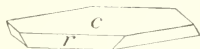
The pleochroism exhibited by the Cowee rubies is very marked, some of them being a very rich pigeon-blood red in the direction of the vertical axis—that is, looking down upon the basal plane—and changing to an almost pinkish-white color when viewed at right angles to this or looking through the prism. The pleochroism which nearly all the deep-colored varieties of corundum gems exhibit is one of the means of identifying a corundum gem; this often interferes with the cutting.

The ruby crystals<sup>1</sup> from the Cowee Valley show a very wide variation in their development. Although many of the crystals are so striated that no crystallographic measurements were possible on the reflecting goniometer, the faces were readily identified by means of the contact goniometer. On some of the crystals the faces were bright

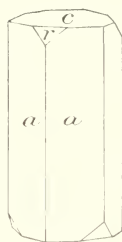
<sup>1</sup> Am. Jour. Sci., 4th series, Vol. VIII, 1899, p. 379.



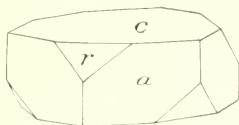
1



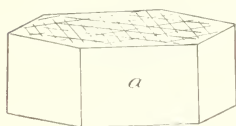
2



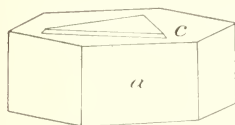
3



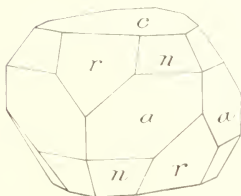
4



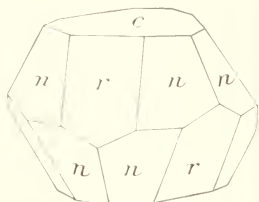
5



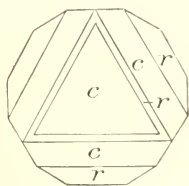
6



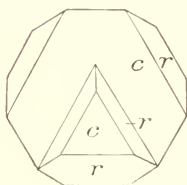
7



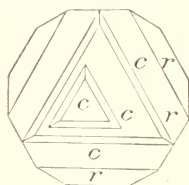
8



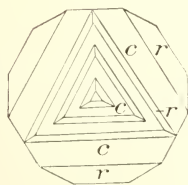
9



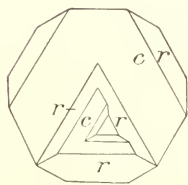
10



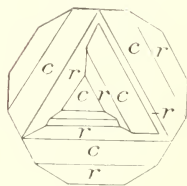
11



12



13



14

RUBY CRYSTALS FROM COWEE VALLEY, MACON COUNTY, N. C.



and smooth, making them well adapted for measurement on the reflecting goniometer. These crystals are shown on Pl. III.

In the crystals examined two common habits were noticed; one is shown in figs. 1 and 2 of Pl. III, and is a combination of the base  $c$  (0001) and the unit rhombohedron  $r$  ( $10\bar{1}1$ ); the other is represented by figs. 3-6 of Pl. III, where the prism  $a$  ( $11\bar{2}0$ ) is very prominently developed. The rhombohedral crystals vary from those in which the base and the rhombohedron are disproportionately developed, the base having a diameter of 12 mm. and the rhombohedron of only 1.5 mm., to some (fig. 1 of Pl. III) in which the base and the rhombohedron are nearer one size. The majority of these crystals have, however, the base more largely developed, thus giving the crystals a flat, tabular appearance. This rhombohedral development is very similar to the sapphires from Yogo Gulch, Montana, described on page 52.<sup>1</sup>

On some of the prismatic crystals the prism reaches a length of nearly 15 mm. in the direction of the  $c$  axis, and has the rhombohedron  $r$  but slightly developed (fig. 3 of Pl. III), while on others the prism is very short and the rhombohedron is sometimes wanting, as represented in figs. 4 and 5 of Pl. III.

Another habit of these crystals is shown in figs. 7 and 8 of Pl. III, where the pyramid  $n$  ( $2\bar{2}43$ ) is well developed. This face was identified by means of the contact goniometer, the measured angles approximating closely to those calculated. The usual form of these crystals is shown in fig. 7 of Pl. III, where the faces  $c$  (0001),  $a$  ( $11\bar{2}0$ ),  $r$  ( $10\bar{1}1$ ), and  $n$  ( $2\bar{2}43$ ) are nearly equally developed. On some of the crystals the prism is very prominent, being 8 mm. in length in the direction of the  $c$  axis, while the pyramid is only 1.5 mm.; on others the pyramid is only very slightly developed. A few crystals were examined which showed only the presence of the base, the rhombohedron, and the pyramid, as represented in fig. 8 of Pl. III. The crystals, measuring up to 7 mm. in diameter, were doubly terminated and nearly perfect in their development.

The crystals represented by fig. 7 of Pl. III are similar to those described by Bauer<sup>2</sup> from the Burma district, and are almost identical in form with the sapphire crystals figured by me, from Emerald Bar, Canyon Ferry, Meagher County, Mont. (p. 50).

Although both the basal and rhombohedron planes are very often striated, it is only on the basal planes that the striations are sharp and distinct and can be measured. The striations are parallel to the three intersections of the base  $c$  and the rhombohedron  $r$  as shown in fig. 5 of Pl. III.

A very common development that was noticed on nearly all the flat rhombohedral crystals and on many of the prismatic crystals is a

<sup>1</sup> Also Am. Jour. Sci., 4th series, Vol. IV, 1897, p. 424.

<sup>2</sup> Neues Jahrbuch für Min., Geol., und Pal., Vol. XI, 1896, p. 209.

repeated growth on the basal plane of the rhombohedron  $r$  ( $10\bar{1}1$ ) and the base  $c$  ( $0001$ ), as represented in figs. 1-6 of Pl. III.

To illustrate better the variation in these growths, a series of drawings, figs. 9-14 of Pl. III, have been made in basal projection. In figs. 9 and 10 of Pl. III, which represent the more common development of these repeated growths, there is but one secondary rhombohedron and base, which sometimes has one of its rhombohedron faces a continuation of one of the rhombohedron faces of the crystal. Figs. 11 and 12 of Pl. III represent the repeated growths, the faces of which are separate and distinct from one another and from the faces of the main crystal. In the crystals represented by fig. 12 of Pl. III, the basal plane of the crystal has the appearance of being striated with triangular markings when the secondary growths are but slightly developed. In figs. 13 and 14 of Pl. III is represented a series of growths where a number of the rhombohedron faces coincide.

Some of the pyramidal crystals (figs. 7 and 8 of Pl. III) also show the development of the secondary growth of rhombohedron and base. The thickness of the rhombohedron of the secondary growth varies greatly: some are so thin that they appear like striations; some are 2 mm. in thickness. A few crystals were observed on which there was a secondary growth parallel to the prism  $11\bar{2}0$ . This same style of development has been described by Baner<sup>1</sup> as occurring in the Burma rubies.

The sapphire crystals from Montana, described on page 53, are strikingly similar in this respect to the Cowee rubies. Among the most noticeable associated minerals of these Cowee rubies is a delicate rose-colored garnet of great brilliancy, to which the name rhodolite<sup>2</sup> has been given. The rhodolite usually occurs in waterworn pebbles, but it has been found in very small dodecahedrons, and its close connection with the rubies in the small crystals of rhodolite inclosed by the garnet has already been mentioned.

The other accompanying minerals are: Quartz, rarely as pseudomorphous dodecahedrons; corundum crystals, of pale-blue, amethystine, and pink shades; spinel (pleonaste); gahnite, in octahedral crystals; chromite (rare); rutile; menaccanite; bronzite (transparent); tremolite; hornblende; iolite (colorless); cyanite; fibrolite; staurolite in perfectly transparent fragments of a garnet-red color; monazite in small crystals; zircon, small, brilliant crystals, and also the variety cyrtolite; pyrite; chalcopyrite; pyrrhotite; sphalerite; sperrylite in minute crystals; and gold.

Much of the work that has been done in Cowee Valley has been in the nature of prospecting to locate the extent of the ruby-bearing gravel and if possible to locate the origin of the rubies themselves. No work was done in the valley during the past year, but it is stated

<sup>1</sup> Loc. cit., p. 209.

<sup>2</sup> Am. Jour. Sci., 4th series, Vol. V, 1898, p. 294.

upon good authority that work will be begun again in the coming spring.

At the Mincey mine, Ellijay Creek, ruby corundum has been found from which several small stones could be cut. This occurs at the same locality as the bronze corundum, described below.

Another locality that is worthy of mention, and one that gives some promise of making a satisfactory showing in course of development, is the so-called gem mine on the property of Dr. C. Grimshawe, of Montvale, Jackson County, N. C. Rubies of good color, from which a number of fine but very small stones have been cut, have been found in the gravels of the stream. Blue and yellow corundum of gem quality is associated with the rubies. By following up the gravels the corundum was located in a small vein in the decomposed peridotite.

At the Cullakeence mine, Buck Creek, and near Elf, on Shooting Creek, Clay County, N. C., masses of emerald to grass-green amphibolite are found, through which are disseminated particles of pink and ruby corundum, ranging in size from that of a pea to some as large as hickory nuts. The corundum is not of gem quality, but the combination of the green amphibolite and pink corundum makes very beautiful specimens, and if the rock is hard enough to admit of a good polish, this occurrence might furnish a decorative or ornamental stone of some value.

At the Mincey mine, on Ellijay Creek, Macon County, and about  $2\frac{1}{2}$  miles northeast of Corundum Hill, there occurs a peculiar brown or bronze corundum, known locally as "pearl corundum," which shows distinct asterism, both by natural and artificial light, when the stone is cut en cabochon. In natural light these corundums all show a bronze luster and are somewhat similar to the cat's-eye, but in artificial light the star is more distinct. Most of the bronze corundum is in rough crystals, but some have been found that have the prismatic faces smooth and well developed, and these are often dark, almost black, in color.

Asterism has been noticed in many of the rubies and sapphires from Cowee Valley and in a few of the sapphires from the Montana deposits. This asterism, according to Von Lasaulx, is sometimes produced by rifts due to the basal parting. These rifts, when examined with the microscope, are seen to be very thin, sharp, and rectilinear, and are parallel to the edge of the prism onto base.

In other cases asterism is undoubtedly due to the rutile or other

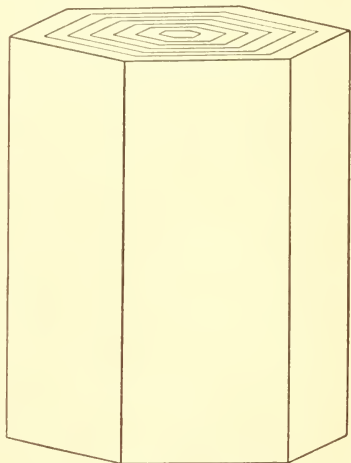


FIG. 7.—Corundum crystal, showing concentric hexagons on basal plane.

mineral that is inclosed in the sapphires, which intersect each other at angles of  $60^\circ$ , and form a "sagenite web" or similar structure.

On many of the corundum crystals, especially of the sapphire variety, concentric hexagons were observed on the basal plane, as represented in fig. 7. The edges of the hexagon are parallel to the edges of the prism faces onto base, and the plane of the hexagon is parallel to the base. In a few of the transparent crystals this hexagon was observed as a web in the midst of the crystal, the plane of the web being parallel to the basal plane.

#### ORIENTAL SAPPHIRES.

The finest sapphires that are known are found in Burma and Ceylon, and have the rich, deep-blue color for which the oriental stone is noted. Sapphires of a rich, velvety blue and some very good stones of a lighter color have been obtained from Simla Pass, in the Himalaya Mountains. Siam has also produced some sapphires of very good color. The sapphire corundum from Australia is generally of an opaque, milky-white color.

#### NORTH CAROLINA SAPPHIRES.

No corundum gems were found in the United States until the opening of the Corundum Hill corundum mine at Cullasagee, Macon County, N. C., in 1871. This corundum is mined for abrasive purposes, but in certain parts of the deposit crystal corundum is occasionally found that is of a decided gem character, and, again, many of the fragments of the corundum have certain portions that are transparent. A number of very handsome dark-blue sapphires from this mine are in the United States National Museum, one of which weighs a carat.<sup>1</sup>

Yellowish and blue colors in the same specimen are rather common, and are sometimes sharply separated into consecutive bands, while in other specimens the colors merge into one another.

Sapphire gems of all the different colors have been found at Corundum Hill, and I have in my collection cut gems representing all these various colors. Many of them are, however, very small.

During the past ten years but few gems have been obtained from this mine, for the reason that the portion of the deposit from which these crystals were formerly obtained has not been worked. In the alluvial deposits below this portion of the mine many handsome crystals can be obtained by washing the gravel.

The green sapphire, which is the oriental emerald, is one of the rarest of gems. The Corundum Hill mine is the only place in this country at which the emerald-green sapphire has been found, and it

<sup>1</sup> Kunz: *Gems and Precious Stones of North America*, 1890, p. 40.



MAP SHOWING LOCATION OF MONTANA SAPPHIRE DEPOSITS

BY  
JOSEPH HYDE PRATT

Scale

0 10 20 30 40 50 MILES

X INDICATES SAPPHIRE DEPOSITS.  
1900.



occurs very sparingly here, although the yellowish and light-green colors are not uncommon. What is probably the finest known specimen of the oriental emerald in the world came from this mine, and is now in the Bement collection. It is a crystal 4 by 2 by  $1\frac{1}{4}$  inches; part of it is transparent, and several very fine gems could be cut from it.

At the Sapphire and Whitewater corundum mines, near Sapphire, Jackson County, N. C., fragments of sapphire of a fine blue color have been found, from which small but good gems have been cut.

Associated with the green amphibolite rock near Elf post-office, Clay County, N. C., deep-blue sapphires have been sparingly found. These bear the same relation to the amphibolite as the red and pink sapphire described on page 45.

#### MONTANA SAPPHIRES.

The only systematic mining that has been undertaken for sapphires is in Montana. Sapphires were first found in this State by miners who were washing the gravels of the bars on the Missouri River, to the east of Helena, for gold. These were first described in 1873 by J. Lawrence Smith,<sup>1</sup> but it was not until 1891 that actual mining was begun. During that year a number of companies were organized to work these bars for sapphires.

These bars are located from 12 to 18 miles east and northeast of Helena, and have been followed for a distance of about 12 miles from Canyon Ferry down the river to American Bar. At various intervals these bars have been worked for the sapphires and are designated by the following names, starting with the one that is farthest up the river: Emerald Bar, Cheyenne Bar, French Bar, Spokane Bar, Metropolitan Bar, Ruby Bar, Eldorado Bar, Dana Bar, and American Bar. The location of these bars is shown on the map (Pl. IV).

A few sapphires have been found as far down the river as Beartooth, but sapphires have not been found in large quantity below American Bar.

Above Emerald Bar there have been no sapphires found on any of the bars, but in the gravel of Magpie Gulch, less than a mile above Emerald Bar (at Canyon Ferry), many sapphires have been found by miners who were washing the gravel for gold. No sapphires have been found in situ in this gulch, but Kunz<sup>2</sup> has noted the occurrence of sapphires that were found in a dike of vesicular mica-augite-andesite which was about 6 feet wide and cut through the green slate below the gravels. In the gravel deposits at French Bar, about 3 miles below Canyon Ferry, a narrow dike was encountered last summer, 3 to 6 feet in width, that had greenish sapphires scattered sparingly through it.

This dike was encountered about 50 feet above the river and its

<sup>1</sup> Am. Jour. Sci., 3d series, Vol. VI, 1873, p. 185.

<sup>2</sup> Min. Mag., Vol. IX., 1891, No. 44, p. 396.

strike as it cuts through the slate is N.  $10^{\circ}$  E., the dip being about  $45^{\circ}$  W.

This rock is undoubtedly of the same character as that described by Kunz as occurring at Ruby Bar. From the occurrence of these two corundum-bearing dikes of andesite it would seem that the source of the sapphires found in the various bars along the Missouri River is a series of small parallel dikes with a slight northeast-southwest trend, like those described. As the sapphires are scattered so sparingly through these dikes, the amount of decomposition and erosion that was required to liberate those that are now found in the gravels must have been simply enormous.

The beds of gravel in which the sapphires occur are from 10 to 50

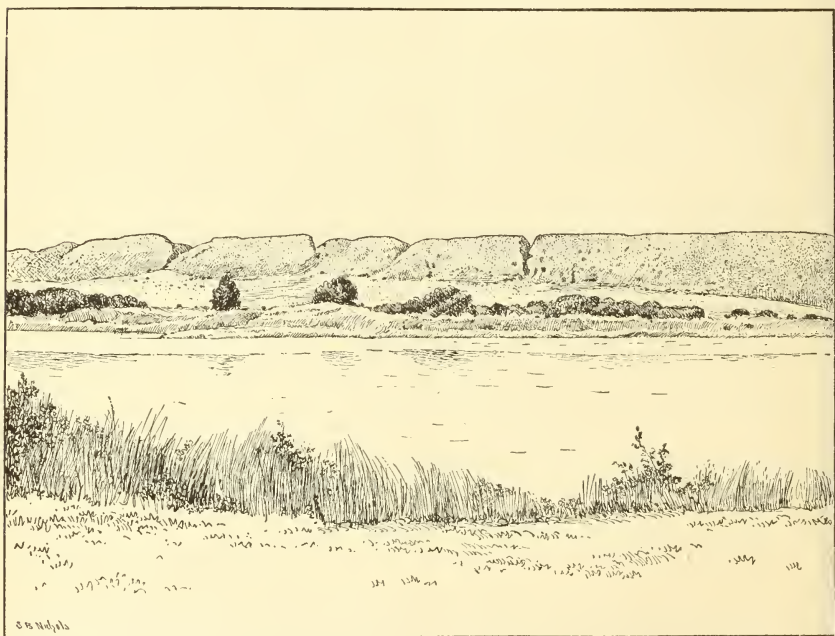


FIG. 8.—Spokane Bar sapphire deposits, Lewis and Clarke County, Mont.

feet thick and rest for the most part upon slate, in bluffs that rise nearly 50 feet above the river. At Emerald Bar the gravel beds are nearly 130 feet above the river and rest upon granite rock.

Most of the mining has been done at Spokane and Eldorado bars. The former locality is near the center of the sapphire deposits and on the west side of the river about 16 miles due east of Helena. In 1890 these beds of gravel, which are 8 to 18 feet thick, were extensively mined by an English company known as the Montana Sapphire and Ruby Company. The gravels were washed by hydraulic methods and a great many gems were obtained, most of which were sent to England. This company also controlled or owned French Bar and Dan Bar on the west side of the river and Eldorado Bar on the east side.

It was reorganized in 1897 as an American company, known as the Eldorado Gold and Gem Company, with A. N. Spratt, of Oakland, Cal., president, and Frank Spratt, of Helena, Mont., manager. No work has been done at any of the bars by the present company. This bar is shown in fig. 8, the bluff rising from the river being 30 to 50 feet high.

Directly across the river from Spokane Bar, but about three-fourths of a mile from the river, is Metropolitan Bar, which has been worked during the summer of 1899 by different men who have staked out individual claims. The gravels are from 6 to 20 feet thick, and are washed in hand rockers, the water being obtained from shallow wells. Several of the claims are owned by Robbin Bird, Charles Johnson, and John Durrant, of Helena, Mont.

Above Spokane Bar, French Bar, Cheyenne Bar, and Emerald Bar no regular mining has been done during the last few years, but frequently different persons have worked in the old drifts for a few days at a time, washing by hand the gravel obtained.

A large part of the work done at Emerald Bar has been under ground, by means of shaft and drifts. Henry Crittenden, of Canyon Ferry, has done a large part of the work here, and still controls the deposits.

Below Spokane Bar, at Dana Bar, Eldorado Bar, and American Bar there was no mining for sapphires during 1899.

Most of the gems that have been obtained from these bars during 1899 have been put on the market through the Helena Lapidary Company, of Helena, Mont., of which William Knuth is manager. Mr. Knuth has done considerable work on these bars, and has been instrumental in the development of the Montana gem fields.

As mining investments these sapphire deposits have not thus far been financially successful, partly on account of the heavy capitalization of the companies who have bought the mines and partly on account of the color of the stones. They are, for the most part, of a pale-greenish or greenish-yellow color, and do not command a very high price in the market. Occasionally pink and yellow ones have been found that have cut good gems. Stones approaching a red or blue color are, however, extremely rare.

There are still a great many sapphires in the gravels that have not been worked, but on account of their color it is rather doubtful whether under the most favorable conditions it will pay to mine them.

The crystals from all these bars show the same development, and are prismatic in habit. The prism,  $a$  (11 $\bar{2}$ 0), is always present, and is usually in combination with the base,  $c$  (0001), and the unit rhombohedron,  $r$  (10 $\bar{1}$ 1), as represented in fig. 9, *A*. Some of the crystals have the prism very short and the rhombohedron is wanting, giving the crystal a very tabular appearance (fig. 9, *B*). A pyramid of the second order,  $u$  (22 $\bar{4}$ 3), was observed on some of the crystals in addition to the base and unit rhombohedron, and is represented in fig. 9, *C*.

The crystals are usually rough and more or less striated, so that no measurement could be made upon the reflecting goniometer, but sufficiently accurate measurements could be obtained with the contact goniometer to identify the faces.

The largest crystal that has been observed from any of these bars was one from Eldorado Bar that was nearly an inch long and three-eighths of an inch in diameter.

A repeated growth was observed on some of these crystals, but not in the variety of forms seen in the Cowee rubies (p. 43) and the Yogo Gulch sapphires (p. 52). Only one form of growth was observed, represented in fig. 9, *A*, which is a combination of the unit rhombohedron and the base.

Since the discovery and mining of sapphires from the Missouri River bars sapphires have been found at three other localities in Montana—at Rock Creek, Granite County; at Cottonwood Creek, Deerlodge County; and at Yogo Gulch, Fergus County.

The first two localities are about 80 and 30 miles southwest of those on the Missouri River, and the last one is about 80 miles to the north-

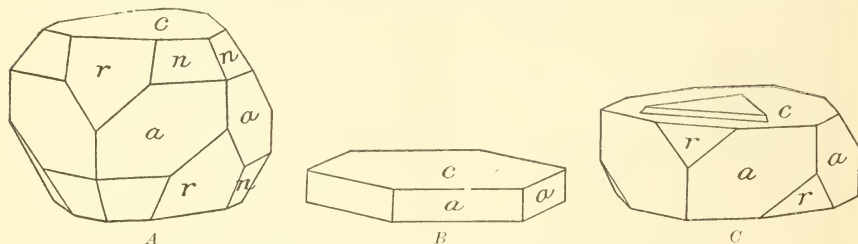


FIG. 9.—Sapphire crystals from Missouri River bars, Montana.

east. From these sapphire deposits stones of deeper colors have been obtained, those from the first two being of all colors from blue to red, while those from the last are all blue.

#### ROCK CREEK SAPPHIRES.

For information concerning the sapphire deposits of Rock Creek, I am indebted to Mr. William Knuth, of Helena. All the sapphires that have thus far been found in this section are in the gravel deposits on the West Fork of Rock or Stony Creek, in the southern part of Granite County, about 35 miles southwest of Phillipsburg, the county seat, and 30 miles nearly west of Anaconda, Deerlodge County. (Pl. IV.)

The sapphires are found in rather a limited area, which is bounded roughly by the gravels of Cold Creek, Myers Creek, tributaries of the West Fork of Rock Creek, and that portion of Rock Creek lying between them.

These gravels were extensively worked during the summer of 1899, principally by William Knuth, of Helena, and William Moffitt, of Phillipsburg. Altogether about 200,000 carats of rough sapphires

were obtained. Of these about 12,000 carats are fit for cutting. In color they are much more varied than those from the Missouri River bars, and the prevailing color, which is greenish to bluish green, is deeper. No deep-blue sapphires like the oriental stones have been found, but paler blue ones have been obtained, from which very handsome sapphires 2 or 3 carats in weight have been cut. Some of the finest yellow sapphires (oriental topaz) that I have ever seen have been found at Rock Creek. One of these weighed close to 2 carats when cut. Pale green and bluish green are among the common stones, some cutting gems of 5 to 8 carats in weight. A number of beautiful pink sapphires have also been found.

Few red and ruby-colored crystals have been found and none that would cut a gem over a twelfth of a carat in weight. These colors are extremely rare in the Montana sapphire deposits.

The crystals and fragments of sapphires that are found in these gravels do not show as much abrasion as those from the Missouri River, probably because they have been carried a shorter distance from where they originated.

In habit the crystals are very similar to those already described from the Missouri River, and fig. 9 will also illustrate very well the character of the Rock Creek crystals. One type that is very noticeable is a short prismatic crystal, whose diameter nearly equals its length. A parallel growth on the basal plane is only occasionally observed, and is composed of the basal plane and unit rhombohedron.

No sapphires have as yet been found in situ, but a few have been found in the gravels that were embedded in the original matrix. Mr. Knuth, to whom I showed a specimen of the andesite containing sapphires from French Bar, said that it very closely resembled the small fragments of rock carrying sapphires that he had found at Rock Creek. It is not at all improbable that these sapphires originated in the same type of rock as those of the Missouri River and that small dikes of andesite will be found in the divide between Myers, Cold, and Quartz creeks. A very few sapphires have been found on Quartz Creek.

While the sapphire gems from Rock Creek do not command so high a price as the ruby and the deep-blue sapphires, and are regarded more as fancy stones, they are coming to be quite highly prized by many who are acquainted with them. As yet but few of the Rock Creek sapphires have been put on the market except locally at Helena, and it seems to me that it can be confidently predicted that these sapphires will become important in the jewelry trade when they are once known.

#### COTTONWOOD CREEK SAPPHIRES.

The sapphire deposits on Cottonwood Creek are in Deerlodge County, about 30 miles southwest of Helena and 10 miles east of Deerlodge, the county seat. There has not been a great deal of work done on

this creek, so that the extent of the sapphire-bearing gravels is not known. The sapphires are similar in character to those of Rock Creek, but they are apt to be of lighter color and not of such a variety of colors. What little work was done on the creek during the past summer was by Franz Cobalt, of Helena, and according to him there were but few sapphires taken out of the gravels. Future development at this locality may show these deposits to be of considerable importance and extent.

#### YOGO GULCH SAPPHIRES.

The sapphires that are the most widely known and that have attracted the most attention have been obtained in Fergus County near the entrance of Yogo Gulch, on the Yogo Fork of Judith River. This locality is on the eastern slope of Prospect Ridge of the Little Belt Mountains, about 75 miles northeast of Helena and 15 miles a little south of west of Utica, which is the nearest town, and which is on the Judith stage line. The sapphires were first found in the gravels of Yogo Fork, and in following these up the creek their original source was located in dikes that extend across the county for a mile and a half.<sup>1</sup>

There are two parallel dikes about 800 feet apart, with a general east-west trend, which vary in width from 15 to 75 feet. The mineralogical composition of the rock shows that it has a close affinity with minette and shonkinite, as described on page 28.

The alluvial deposits below these dikes have been pretty thoroughly worked for the sapphires, and mining operations are now confined almost entirely to the dikes themselves. These dikes, the upper portion of which is thoroughly decomposed, have been worked by means of open cuts, the limestone making fairly firm walls. By hydraulic processes the decomposed rock was readily broken up and washed into sluice boxes. As the mining extended deeper the rock was much less altered and it was necessary to leave a great deal of it exposed to the atmosphere from one season to the next, before it could be broken up and run through the sluice boxes. At a number of points the almost perfectly fresh rock has been encountered, and from this it will be a difficult problem to separate the sapphires. The percentage of sapphires in the rock is small and if it were the unaltered rock that had to be worked for them the deposit would not be of economic importance.

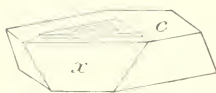
The sapphires occur embedded in this rock in distinct crystals from less than a millimeter in diameter to some that were over 15 mm. Their color, as far as I have observed them, is always a blue, varying from light blue to a very few that showed the dark blue of the Ceylon stone. The prevailing color is a bright blue.<sup>2</sup>

<sup>1</sup> The geology of the district and a full description of the mines and workings, by W. H. Weed, will be found in the Twentieth Ann. Rept. U. S. Geol. Survey, Part III, 1899, pp. 454-460.

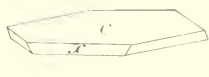
<sup>2</sup> Kunz: Am. Jour. Sci., 4th series, Vol. IV, 1897, p. 420.



1



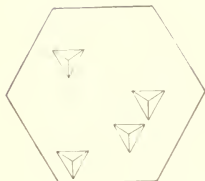
2



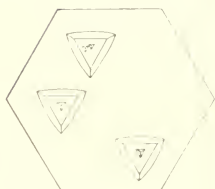
3



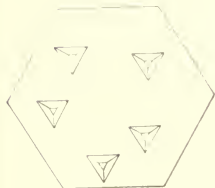
4



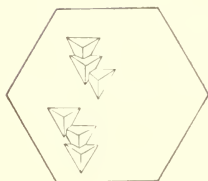
5



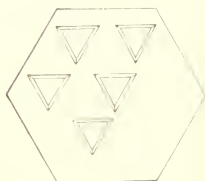
6



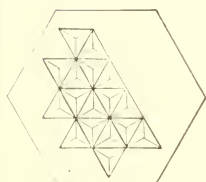
7



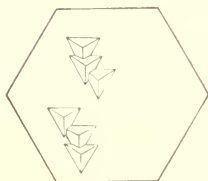
8



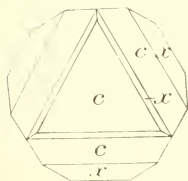
9



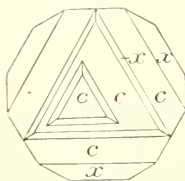
10



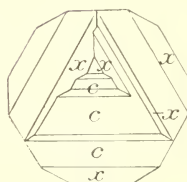
11



12



13



14



While the color of these sapphires is not as dark as the highly-prized Ceylon stones, they show a richness and brilliancy not equalled by the oriental stone. They not only show a strong rich color by transmitted light, but their color is almost as good by reflected light. Then again, while many blue sapphires make beautiful day stones but are dull at night, the Yogo sapphire is a very brilliant night as well as day stone.

The crystallography of these sapphires is markedly different from that of the sapphires of the Missouri bars and Rock Creek (page 50). The latter all show a prismatic development, while the former are all rhombohedral crystals, none of which show the presence of any prism face.<sup>1</sup>

The crystals are etched and striated to such a degree that no crystallographic measurements on the reflecting goniometer were possible; but sufficiently accurate angles were obtained with the contact goniometer to permit the identification of the faces. The only two faces that could be identified were the base  $c$  (0001) and the rhombohedron  $x$  ( $30\bar{3}2$ ) which is a new face for corundum. On one crystal two very small faces were observed which were too small to be measured with the contact goniometer, but were probably the faces of a pyramid of the second order.

In determining the rhombohedron, ten or more independent measurements were made of  $c \wedge x$ . These varied from  $66^\circ$  to  $68^\circ$ , but approximated closely to  $67^\circ$ , which agrees very well with the calculated value,  $67^\circ 3'$ , for  $0001 \wedge 30\bar{3}2$ . These crystals are represented on Pl. V.

The crystals are developed, as shown in figs. 1, 2, and 3 of Pl. V, the prevailing type being like fig. 3 of Pl. V. The crystals vary from those where the base is very largely developed, having a diameter of 8 mm., while the rhombohedron is only 1 mm., to those that have the base and the rhombohedron equally developed (fig. 1 of Pl. V). Where the faces are more equally developed, the rhombohedral faces are generally rounded.

The basal plane often shows characteristic striations which are parallel to the three intersections of the base  $c$  and the rhombohedron  $x$ , as shown in fig. 4 of Pl. V. These lines are sharp and distinct and on the very flat crystals can easily be measured when examined under the microscope. The rhombohedral faces are very roughly striated without showing any distinct parallel lines.

One very common development of these crystals is a repeated growth on the basal plane of the rhombohedron  $x$  ( $30\bar{3}2$ ) and the base  $c$  (0001), as represented in fig. 2 of Pl. V. These growths are exceedingly varied, as is shown in figs. 11–14 of Pl. V, where they are drawn in basal projection. In fig. 11 of Pl. V there is but one secondary rhombohedron and base, which has one of its rhombohedron faces a continuation of one of the rhombohedron faces of the crystal.

<sup>1</sup> Am. Jour. Sci., 4th series, Vol. IV, 1897, p. 424.

Fig. 12 of Pl. V represents a repeated growth, each face of which is entirely distinct from the faces of the main crystal. In fig. 13 of Pl. V there are represented two, and in fig. 14 of Pl. V a series of such growths, where a number of the rhombohedral faces coincide. These growths occur most frequently on the flat crystals. The thickness of the rhombohedron rarely reaches 1 mm. and often they are so thin that they appear like striations.

This repeated growth is very similar to that described as occurring on the Cowee rubies (p. 43). Bauer,<sup>1</sup> in an article entitled "Ueber das Vorkommen der Rubine in Birma," has described this same style of development as occurring on the Burma rubies, but it is not so general as on the Montana corundums.

*Etching figures.*<sup>2</sup>—The etching figures which were observed on nearly all the crystals examined were on the basal plane. The figures are very perfect, and although showing many different forms, they all have a rhombohedral symmetry. Fig. 5 of Pl. V represents the common etching figure, which is a rhombohedral depression terminating in a point. The edges of the depression are sharp and well defined, as are also the intersections of the rhombohedral faces of the depression. These rhombohedral faces were smooth and gave fair reflections of the signal on the reflecting goniometer. In measuring them the entire crystal except the depression to be measured was covered with a thin coating of wax. Two different crystals were measured, which gave for rhombohedron on rhombohedron  $22^{\circ} 30'$ ; this corresponds to the rhombohedron 10 $\bar{1}7$ , for which the calculated value is  $21^{\circ} 50'$ . Figures of the same style were observed whose edges were parallel to those of the negative rhombohedron; these, however, are not common in isolated forms.

Another common form is represented in figs. 7 and 9 of Pl. V, where the depression is bounded by the basal plane, which at times is so large that the rhombohedral plane is hardly visible. Fig. 6 of Pl. V represents etching figures, where, on the basal plane of a shallow depression, there is one additional etching figure and sometimes two. These second etching figures are like the common ones shown in fig. 5 of Pl. V. The outer rhombohedral contour of these figures is generally rounded. This is also usually the case with the deeper depressions.

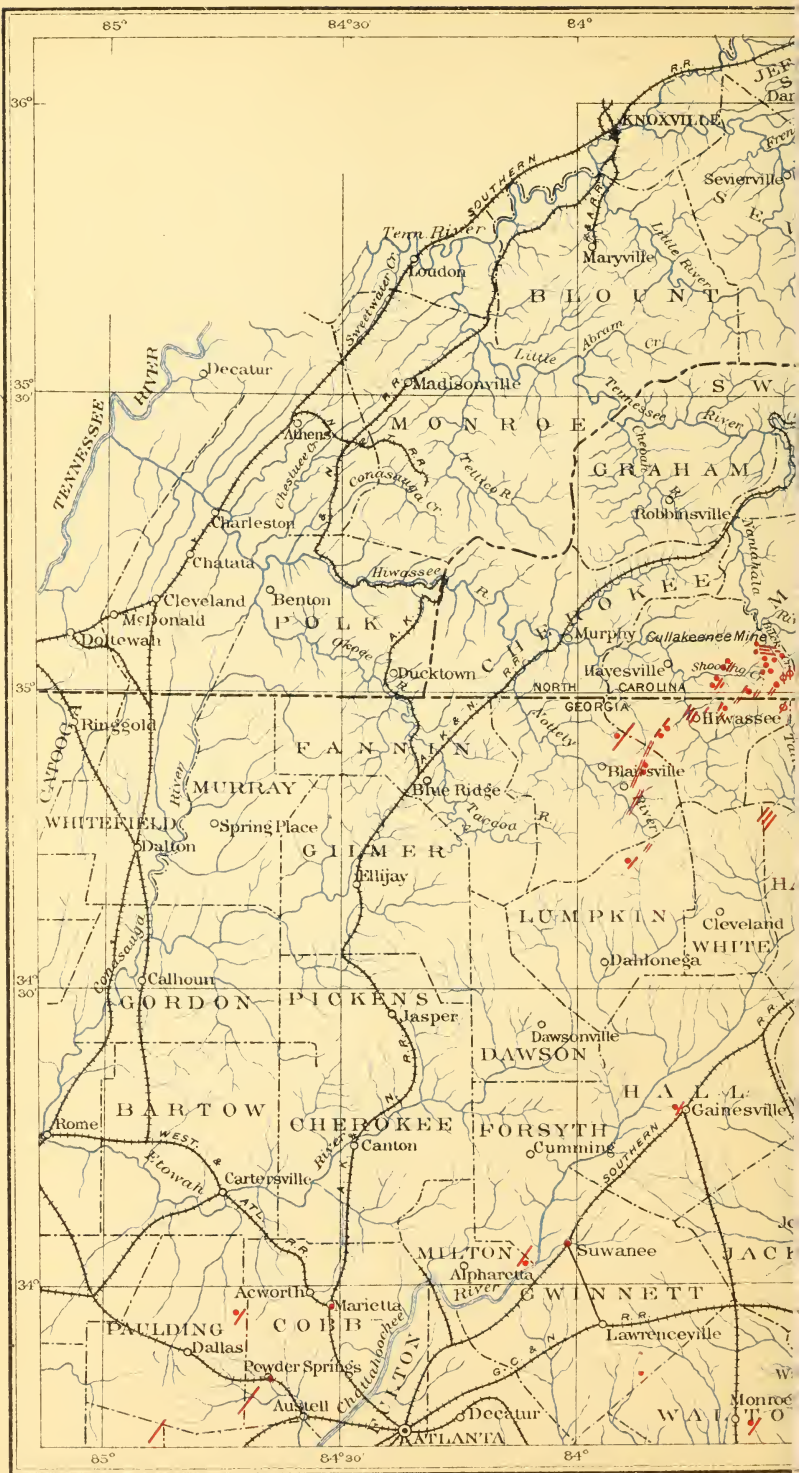
Often the etching figures are intergrown, fig. 8 of Pl. V, and when many of these occur together they have the appearance of raised figures rather than of depressions. This raised appearance is very striking when there is a combination of the plus and minus rhombohedron in parallel position and without overlapping, fig. 10 of Pl. V.

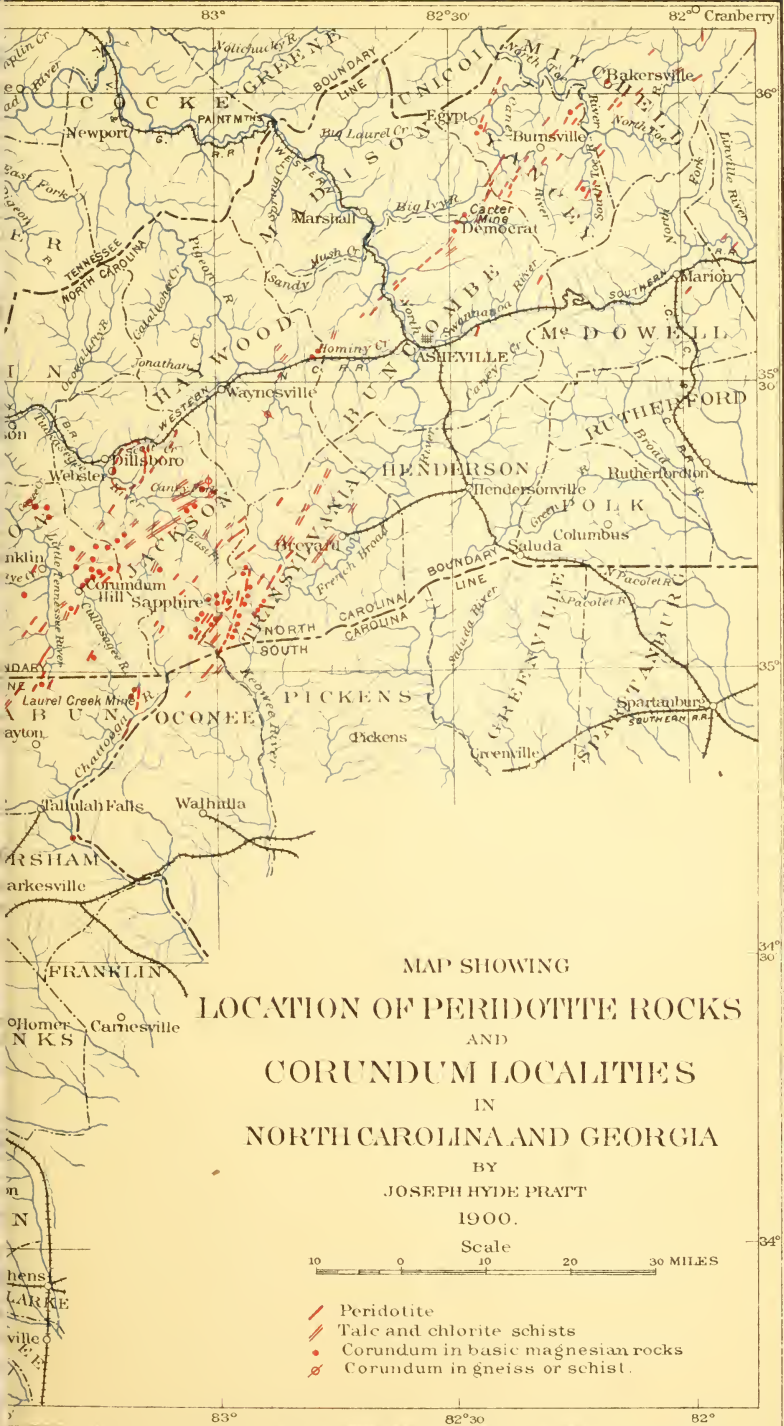
The figures vary considerably in size, but most of them are near 1 mm. in diameter. A few were observed that were nearly 2 mm. in diameter.

<sup>1</sup> Neues Jahrbuch für Min., Geol. und Pal., Vol. XI, 1896, p. 209.

<sup>2</sup> Am. Jour. Sci., 4th series, Vol. IV, 1897, p. 426.









Bauer<sup>1</sup> has described etching figures that he observed on the base 0001 and the pyramid 22 $\bar{4}$ 3 of the Burma rubies. Those on the base are similar to the figures in fig. 5 of Pl. V, except that the outside contour of the rhombohedron is rounded.

These sapphire deposits are now controlled by the New Mine Sapphire Syndicate of Utica, Fergus County, Mont., and London, England, of which Mr. George A. Wells, of Great Falls, Mont., is president. Mr. S. S. Hobson, of Lewiston, Mont., one of the directors of the company, states in a recent letter that 130,000 carats of cuttable material were taken out last season. Besides this there is a large amount of very small crystals and badly flawed larger crystals that are not capable of being cut into gems and that are sold by the ounce. The largest rough stones that have been found weighed 11 to 12 carats, and from these were cut gems weighing 5 to 6 carats. One of the better stones taken out the season of 1899 weighed 4 carats when cut and is valued at over \$75 a carat. All of the material is shipped to London.

That the American gems are being appreciated is shown by the large orders that are received for them from Paris, London, and New York.

#### CORUNDUM.

Under this head are included all the translucent to opaque varieties of all colors, subdivided into block, crystal, and sand corundum. While a sharp line can be drawn between corundum and emery, no such distinction can be made between corundum and sapphire, for many pieces of the former are found that have transparent portions. Many sapphire gems have been found in masses of corundum that were being mined for abrasive purposes.

In the following descriptions corundum deposits have been taken up by States in the order of supposed importance. Many of the beds are briefly noticed, but the larger and more important deposits are described in detail.

#### NORTH CAROLINA.

Most of the corundum localities in North Carolina are, in a general way, indicated on the map (Pl. VI), except the very few that are east of the Blue Ridge. In the following descriptions only those deposits have been considered which have been mined for corundum or which hold out a promising prospect for the mineral. These will be taken up by counties, the more important ones first.

#### MACON COUNTY.

Corundum was first discovered in this county in 1870 at what is now known as the Corundum Hill mine, and mining was begun here about a year later. This mine has become one of the most important

<sup>1</sup> Loc. cit., p. 213.

corundum deposits in this country. It is situated about 8 miles south east of Franklin, the county seat, on the northeast side of Cullasagee Creek, a tributary of the Little Tennessee River.

The corundum found at this mine occurs in peridotite rock, and this has been worked very extensively, especially near the contact of this rock with gneiss. Pl. VII gives a general view of this peridotite formation, and shows to a certain extent the number of openings that have been made in it. The hill is about 350 feet high, the summit being about 500 feet above the level of Cullasagee Creek. Fig. 10 is

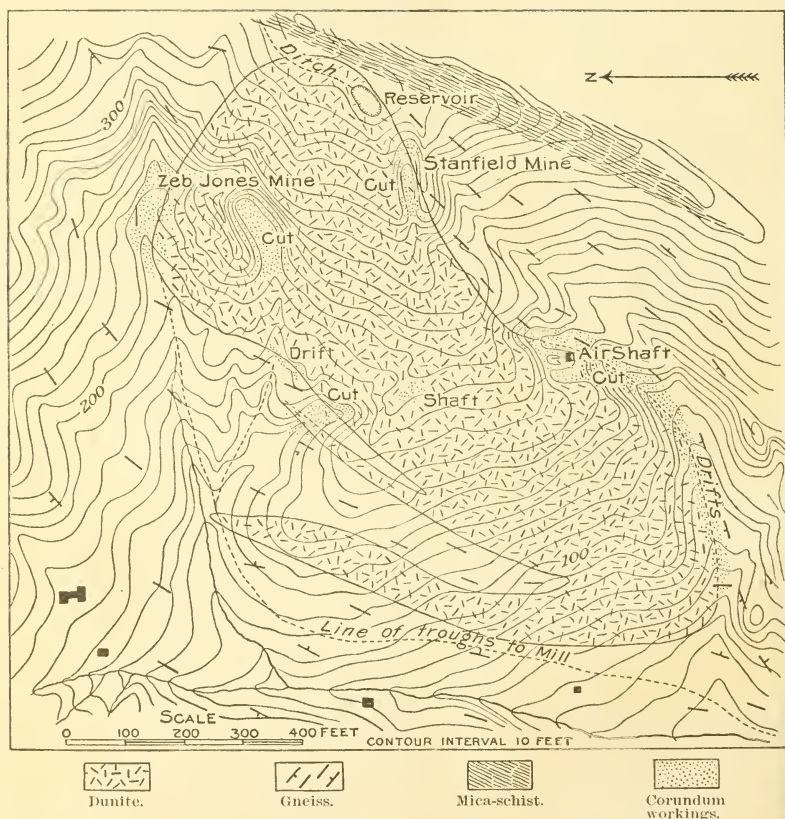


FIG. 10.—Map of the peridotite formation at Corundum Hill, Macon County, N. C.

a topographic map of this same peridotite formation, and shows the location of the various mines. The formation is a rather blunt le shaped mass of the dunite variety of peridotite, and has about 100 acres of surface, over most of which the rock is exposed. As is seen from this map, most of the mines are located near the contact of the dunite with the gneiss or schist, and follow contact veins of corundum. A number of dunite veins have been worked within the formation, but with the exception of the one marked "Shaft" on the map they have all soon pinched out.



GENERAL VIEW OF THE PERIDOTITE FORMATION AT CORUNDUM HILL, MACON COUNTY N. C.





THE BIG VEIN BETWEEN THE PERIDOTITE AND THE GNEISS AT CORUNDUM HILL,  
MACON COUNTY N. C.



Most of the mining has been done on the south side of the formation, where was encountered what is known as the Big vein. This was first mined by means of open cuts and later by tunnels, the last one being about 300 feet below the summit of the hill. Pl. VIII is a view of the entrance to this tunnel, and shows the peridotite rock on the left and the gneiss on the right beyond the cut. For nearly the whole distance of the southern boundary of the dunite formation a cut has been made following the contour of the hill. This cut was sometimes wholly within the gneiss, at other times wholly within the peridotite, and again cutting directly on the contact. The tunnels are all to the left of the cut, and they have encountered corundum almost continuously for a distance of 1,280 feet, reaching nearly to the southeast boundary of the formation. Pl. IX is a view of the upper or southeastern end of this cut, showing the peridotite on the left and the gneiss and schist on the right. The upper part of this cut is known as the Stanfield mine. A tunnel has been run into the hill near the contact, at the head of which the vein of corundum is 8 to 10 feet wide. No work has been done at this mine for a number of years.

On the northeast side of this formation is what is known as the Zeb Jones mine, where there was exposed (July, 1899) a bench of ore 25 feet in depth and 2 to 5 feet in width, uncovered for a distance of 50 feet, which averaged very close to 50 per cent corundum. This vein carries what is known as "buckwheat" corundum, which, as its name suggests, is made up of small, irregular particles of corundum about the size of buckwheat grains.

Numerous dunite veins have been found and worked, but they can be mined profitably only when they are large contact veins, for the reason that they are very likely to pinch out after being worked for a short time.

From these various openings, collectively known as the Corundum Hill mine, block, crystal, and sand corundum ores have been obtained, all of which can be readily cleaned and will make a commercial product that can be used in the manufacture of any kind of corundum wheel. A small amount of garnet is occasionally found associated with the corundum in the vein along the southern contact, but this portion of the ore can be readily eliminated by hand cobbing at the mine. This is the only mine that produced any quantity of corundum during 1899. It is now owned by the International Corundum and Emery Company, of New York, N. Y.

The water of Cullasagee River is utilized for the washing and cleaning machinery of the mill, which is located about a mile and a half below the mine, at Cullasagee. A line of sluice boxes connects the mine with the mill, and all the corundum ore that can be readily broken to pieces is carried down to the mill in these boxes.

There are many outcrops of peridotite on Ellijay Creek, a few miles north of Cullasagee, and at many of them corundum has been found.

The most work that has been done is at the Mincey mine, which is 2 miles northwest of the Corundum Hill mine. At this locality a considerable quantity of corundum has been taken out, which was carried to the mill at Cullasagee and cleaned. Pl. X is a view of this open cut, which was entirely within the formation. Judging by the amount of corundum obtained and by that found near the contact of the dunite with the gneiss, there are good indications of the existence of corundum in quantity along the contact. The corundum that was obtained at this mine was hauled by wagons to the Corundum Hill mine, where it was cleaned. This property is owned by the International Corundum and Emery Company, of New York, N. Y.

Between the Corundum Hill and Mincey mines there is a bold outcrop of dunite on the Gray property, covering about the same surface as that at Corundum Hill. Although there has been no mining here, the little prospecting that has been done has shown corundum to be very thickly scattered along the lower borders of the formation, and many small pits that have been sunk within the formation have encountered corundum. This, in my opinion, is one of the most promising prospects for corundum in Macon County.

A great many of the peridotite formations along Ellijay Creek have been worked a little at different times, and these are mentioned in the lists of corundum localities (p. 83).

*Sheffield mine.*—This mine is in Cowee Township, about 7 miles northeast of Franklin, the county seat, just north of Cowee Creek. The corundum occurs here in amphibole-schist, and is described on page 31. On account of the depth to which decomposition has extended, the solid rock was only observed in the lower portions of the 87-foot shaft, so that nothing definite is known of this corundum-bearing amphibole-schist. The corundum, which is pink in color and which occurs in oval-shaped nodules up to an inch in diameter, has been pretty thoroughly mined down to the hard rock. The corundum is of good quality, and some preliminary tests have shown that it is well adapted to the manufacture of the vitrified wheel. On account of the low percentage of corundum in the rock, it is not at the present time a profitable corundum ore.

The saprolitic ore is readily cleaned, and furnishes a nearly pure commercial product. A small mill has been erected here. This property is owned by the National Abrasive Manufacturing Company, of New York, N. Y.

#### CLAY COUNTY.

*Buck Creek or Cullakeenee mine.*—This mine is in the Buck Creek Valley, about 20 miles southwest of Franklin, Macon County, and 21 miles a little north of east of Hayesville, the county seat of Clay County. These corundum deposits are associated with a compact mass of peridotite, covering about three-quarters of a square mile, the largest



UPPER END OF BIG CUT AT CORUNDUM HILL MINE, MACON COUNTY, N. C.

Peridotite is shown on the left and gneiss and schist on the right.





OPEN CUT ON DUNITE VEIN AT THE MINCEY MINE, MACON COUNTY, N. C.



mass that is known in the Appalachian belt. Fig. 5 (page 22) is a topographic map of this formation, and shows the relation of the amphibolite to the peridotite and the location of the various openings that have been made for corundum. There has been but very little systematic mining for corundum in this locality, and most of the work has been in the nature of prospecting. Numerous cuts and pits have been made at a great many points on the formation, most of which have shown the presence of corundum. The principal work is at the east end of the formation, near the contact of the dunite with the gneiss, where a shaft 40 feet deep was sunk partially on the contact vein. A number of open cuts in this same vicinity have penetrated into the same vein. This vein is different from most of the corundum veins in the peridotite rocks, in that it is composed essentially of plagioclase feldspar and hornblende, which bear a similar relation to each other as the feldspar quartz and mica in the pegmatitic dikes. Pl. XI, A, is a general view of the Buck Creek formation, showing the shaft mine and the location of the contact vein that has been opened. With this exception all the pits and cuts that have been made are within the formation itself, and where they encountered corundum it was in small pockets, the remains of larger dunite veins. Pl. XI, B, shows one of these dunite veins. From the amount of corundum exposed by prospecting and the work done in the shaft, there is without doubt a large amount of corundum associated with these peridotite rocks, and if the mine were more accessible to the railroad it would offer one of the best corundum prospects in the country. At the present time, however, the nearest shipping point is Murphy, which is over 40 miles to the west. The nearest point on the Murphy branch of the Southern Railway is only 18 miles, to which a good road can be built that would not cost much more than the first 18 miles of the road to Murphy. Buck Creek offers ample water supply for running a mill sufficient to clean whatever corundum would be mined here. This property is also owned by the International Corundum and Emery Company, of New York. The ore is not difficult to clean, and, as far as can be judged from a superficial examination, should make a commercial product that can be used in the manufacture of the vitrified wheel.

*Blue Ridge corundum tracts.*—Under this head are included the long bands of corundum-bearing quartz-schist that have been found in the southeastern part of the county and in the adjoining county of Georgia (Rabun County): Parallel bands of this corundum-bearing schist have been followed for a number of miles close to the summit of the Chunky Gal and the Yellow mountains. As is stated on page 35, the amount of corundum in this schist is probably not over 5 per cent, and with such a low percentage of corundum these rocks are not to be considered, at the present time at least, as a source of this mineral.

There are four tracts included under this head, which are described below.

The Scaly Mountain tract is near the headwaters of Beech Creek, a prominent eastern tributary of the Tallulah River, on the southern and southwestern slopes of Scaly Mountain, at the elevation of about 4,500 feet. The corundum-bearing bands of schist have been traced for the distance of about 2 miles, with a general strike of N. 40° E. and with a dip approximately 20°–30° NW. Considerable prospecting has been done in tracing this band of schist, but experiments show that there is less than 5 per cent of corundum in this schist, although some specimens have yielded 12 per cent. The latter were probably pieces broken off along planes of lamination of the schist, while the rest of the piece from which they were broken off carried but little corundum.

The Foster tract is in Georgia, about 1½ miles from Scaly Mountain, and the State line forms its northern boundary. It is on both sides of Falls Branch, one of the smaller western tributaries of the Tallulah River, and is about 3,500 feet above sea level. Here a number of pits have been made and samples of corundum have been obtained which have assayed on an average about 5 per cent of this mineral. There is more garnet associated with the corundum in this ore than in that from any of the other localities.

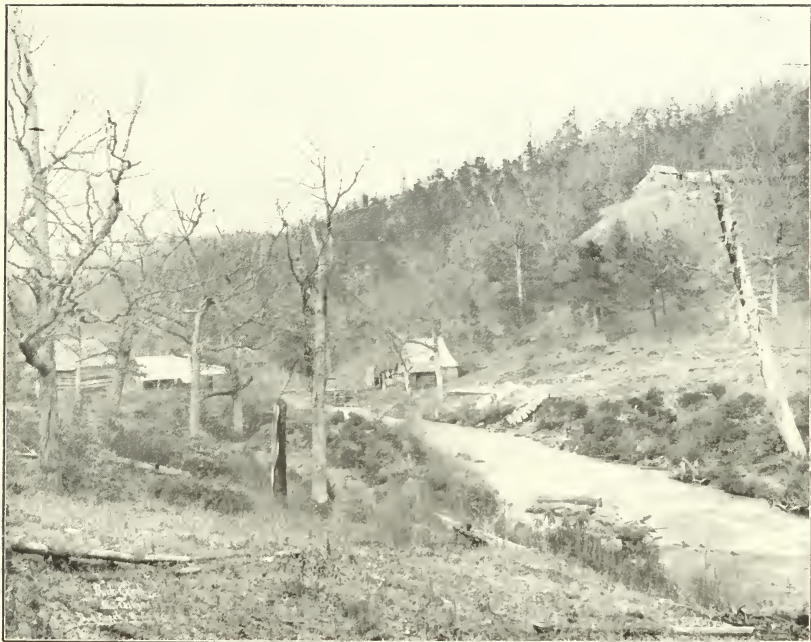
The Yellow Mountain tract is on the north of Scaly Mountain, on the northern slopes of the Yellow Mountains. No prospecting has been done here, and from the indications the ore is the same grade as at the other localities.

The Chunky Gal tract is at the summit and along the western slopes of the Chunky Gal Mountains, near the headwaters of Sugar Cove Creek. With a few interruptions, the corundum-bearing schist has been traced for over 2 miles, with a strike and dip approximately the same as on the other tracts. A number of pits and cuts have been made, from which considerable ore has been taken out and tested, and the tests show the percentage of corundum to be practically the same as at the others.

The corundum bands of the schist in all the tracts vary considerably in width, some being not over a foot or two wide, while others are 18 feet. In these wider bands, however, there are apt to be bands of the normal schist. More or less garnet has been found associated with the corundum in all the schist, and if in any amount would have to be eliminated or it would prevent any commercial corundum obtained from these ores being used in the manufacture of the vitrified wheel.

From the extent of the corundum-bearing schist, there is undoubtedly a large quantity of corundum in this section, but the low percentage of corundum in the rocks makes it very questionable whether they can be profitably worked.

The Corundum Mining and Manufacturing Company, of Philadel-



A GENERAL VIEW OF THE BUCK CREEK CORUNDUM MINE AND PERIDOTITE FORMATION, CLAY COUNTY, N. C.



B DUNITE VEIN OF CORUNDUM IN THE PERIDOTITE FORMATION AT BUCK CREEK, CLAY COUNTY N. C.



phia, Pa., has recently been organized to work the deposits on the Scaly Mountain and Foster tracts. The only mining that has thus far been done consists of an open cut extending 35 feet on the band of corundum-bearing quartz-schist. About 1,000 tons of ore have been taken out, a small portion of which has been crushed and cleaned. The point at which mining was begun is on the southwestern slopes of Scaly Mountain at an elevation of nearly 4,500 feet. The crushing plant has been erected close to the cut. The cleaning mill is about 2,000 feet lower on Scaly Mountain, the crushed ore being conveyed thither in a flume.

No definite method of cleaning has as yet been decided upon. Experiments have been made with jigs and a Bartlett table, but they have not proved very satisfactory. The garnet and magnetite in the ore are to be separated by the electro-magnet. No corundum has as yet been cleaned for the market.

#### JACKSON COUNTY.

Perhaps the most important corundum locality in this county is in the extreme southeastern portion, in the vicinity of Sapphire, extending over into the adjoining county, Transylvania. In this section there is a series of about 30 outcrops of peridotite, which extend in a general northeast-southwest direction. All these outcrops are small, and corundum has been found associated with many of them. The location and relative size of the larger of these outcrops and the places where corundum has been mined are represented on the map, fig. 11. Most of this has been at the Bad Creek and Socrates mines, but the greater part of the work done at any of them has been in the nature of prospecting.

At the Burnt Rock mine, which is located about 5 miles northeast of Sapphire, all the mining has been done within the peridotite formation, and about 10,000 to 12,000 pounds of corundum have been taken out. It is of good quality and occurs in white crystals and knotty nodules. The ore is free from garnet and can be readily cleaned. From the amount of work done here the indications are that there is a considerable quantity of good corundum associated with the peridotite near its contact with the gneiss. The mining at the Brockton mine was also within the peridotite, and about the same amount of corundum was taken out as at the Burnt Rock mine. The corundum occurs in dull-gray crystals, which are easily cleaned and separated from the gangue. These two mines are in Transylvania County. Just below this mine, on the slopes of Poplar Ridge, a vein of corundum was exposed in October, 1900, by workmen who were making a new road. The corundum is massive, and gives good indications of occurring in quantity.

The little work that was done at the Sapphire mine shows a considerable quantity of white and gray corundum, often speckled with blue,

very similar to the corundum found at the Whitewater mine, 6 miles south of the Sapphire mine. The Socrates mine is about three-quarters of a mile southwest of the Sapphire, in a bold outcrop of peridotite. The corundum is in small, knotty nodules and is easily cleaned. A contact vein was encountered, but little work was done to develop it.

The Bad Creek mine has been worked more than any other in this section, and is located about three-quarters of a mile nearly south of of Sapphire. The work done at this mine has been almost entirely on a

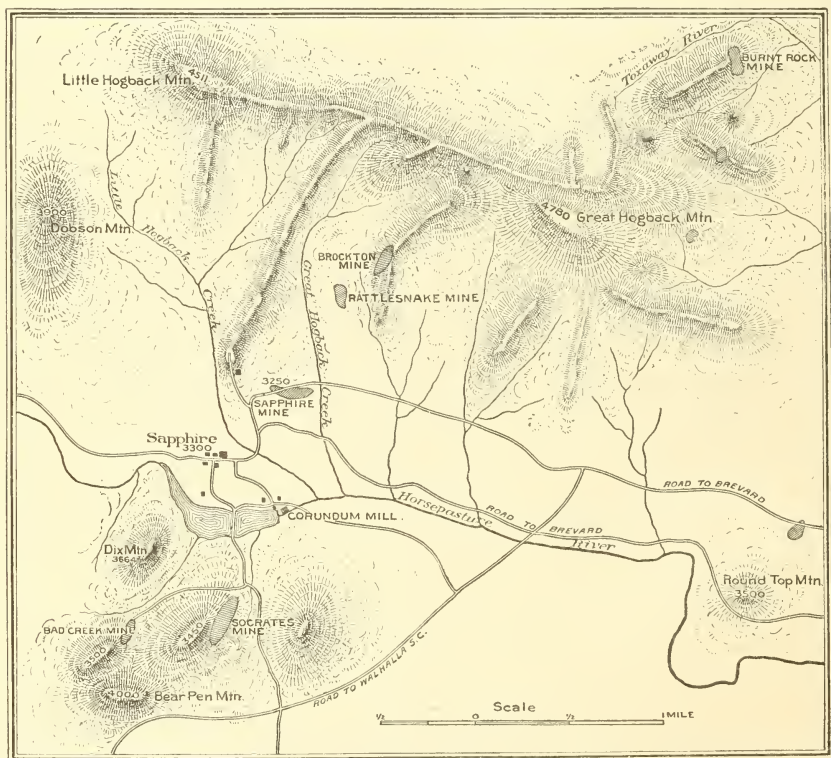


FIG. 11.—Map of the peridotite areas in the vicinity of Sapphire, Jackson County, N. C., showing the location of the different corundum mines.

contact vein which has been exposed for the distance of 130 feet and has been worked at one point to a depth of 60 feet. The corundum ore that was encountered in this vein is of two distinct kinds; in one the corundum is associated with garnet and hornblende, and in the other, which is free from garnet, the corundum is in a matrix of biotite-mica. These two ores should always be kept separate, for the corundum can readily be cleaned and separated from the associated minerals in the biotite ore and will yield a product that can be used in the manufacture of the vitrified wheel; but the corundum can be separated only with difficulty from the ore that contains the garnet. Unless

the garnet can be entirely eliminated this ore will not make a product that can be used for making the vitrified wheel. The vein has an average width of nearly 9 feet, and will carry from 15 to 20 per cent of corundum. All these mines just referred to belong to the Toxaway Company, Sapphire, N. C.

Corundum has been found at a number of the peridotite outcrops between the Bad Creek and the Whitewater mines; and while this does not by any means indicate that there are large deposits of this mineral in these rocks, it does indicate, taking into consideration the corundum deposits already found northeast and southwest of these, that there is a possibility of such deposits, and it makes this section a promising one for systematic prospecting.

#### GEORGIA.

The corundum localities of this State are shown on the map (Pl. VI), which also gives the general location of the peridotite formations that have been observed in this section. Although there is considerable peridotite occurring in the northern portion of the State, it is at but few places thus far that corundum has been found in any quantity, and these are at the extreme northern part, not far from the North Carolina line.

Georgia corundum is well known, and perhaps has the best reputation of any on account of that obtained from the Laurel Creek mine, which, with the exception of the Track Rock mine, is the only one that has produced any considerable quantity of corundum. The peridotite formations are not so large as in North Carolina, nor are the corundum localities so numerous, and it is not probable that there is as much corundum in this State as in North Carolina, although the Laurel Creek mine may be superior to any one thus far located in North Carolina.

*Laurel Creek mine.*—This mine, which is owned by the International Corundum and Emery Company, is located at Pine Mountain, Rabun County, Ga., and is 18 miles from Walhalla, S. C., the nearest point on the railroad. At this locality there is a large outcrop of peridotite, covering several hundred acres, and along the contact of this with the gneiss large deposits of corundum have been found. Several openings have been made, some of which have been worked very extensively. Fig. 12 is a topographic map of this peridotite formation, showing the general location of the cuts and shafts that have been made. As is seen from the map, the formation extends over two small hills, which, on account of their rough and barren nature, offer a sharp contrast to the surrounding country. There is a large open cut (1 in fig. 12) on the east side of the formation, which follows for the most part along the contact, is 200 feet in depth at the lower end, and gradually rises until at the upper end the surface is reached.

At its lower end this cut encountered what is known as the Big vein of massive corundum, the cut having followed on a contact vein of crystal corundum. Pl. XII is a photograph of this cut, which shows the gneiss very distinctly on the left and the peridotite on the right, with the shaft house in the foreground.

The Big vein of massive corundum, for which this mine is noted, is at the foot of the south slope of the hill, and has been followed from the lower end of the cut (1, fig. 12) for a distance of over 300 feet, represented by the dotted lines, with the shaft house (4, fig. 12) near the western end. Although this vein is near the contact of the peri-

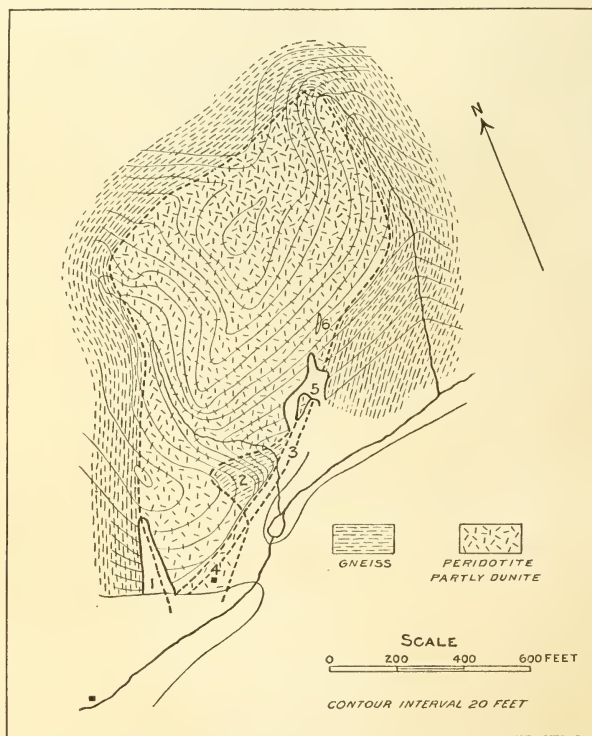


FIG. 12.—Map of the peridotite formation at Laurel Creek, Rabun County, Ga.

idotite with the gneiss, it is separated from it by a band of peridotite and a small vein of sand corundum. There is some doubt whether the block of gneiss (2, fig. 12) is entirely surrounded by the peridotite or whether it penetrates the peridotite from the main mass of gneiss. From what could be seen, and from information obtained from Mr. Andy Evans, foreman of the mine, it has very much the appearance of being entirely inclosed in the mass of peridotite. The Big vein, which has been worked by an inclined shaft 116 feet deep, with tunnels 300 feet in length running from this, has brought the work up to the block of gneiss just referred to, and, according to Mr. Evans,



OPEN CUT ON PERIDOTITE-GNEISS CONTACT AT LAUREL CREEK, GEORGIA.

Shaft house in foreground.



a little work was done farther to the east which showed the corundum vein to extend on the south side of the block of gneiss, and it is not at all improbable that this vein continues as represented by the dotted line 3. Open cuts on the east and west side of this block of gneiss have followed contact veins of corundum. Pl. XIII, *A*, is a photograph of the peridotite formation near the cut on the east side. Little work has been done at Laurel Creek except on contact veins, the principal exception being a small dunite vein (6 in fig. 12) near the west end of the formation, from which considerable corundum was obtained, but the vein soon began to pinch out. Pl. XIII, *B*, is a photograph of this vein, showing both the hanging and foot walls of peridotite. At 5, fig. 12, considerable work has been done, and some large crystals, for which this mine is noted, were obtained here.

This is perhaps the most famous corundum mine in this country, and has furnished ore from which an exceptionally good commercial product has been obtained.

It has not been worked since 1894, when the tunnels and shafts of the Big vein were cut off by the slipping of a large block of the peridotite formation, nearly a 200-foot cube. It is that portion of the formation represented on the map (fig. 12) between the open cut (1) and the cut to the west of the block of gneiss (2).

*Track Rock mine.*—The location of this mine is in the northeastern part of Union County, Ga., on the south side of Track Rock Gap. The corundum occurs in a peridotite formation, which is very much decomposed on the surface, there being very little visible but a mass of chlorite-schist containing more or less actinolite. A tunnel, having its upper end 75 feet below the surface, has been run in on the formation for about 200 feet, with short branching tunnels at several points. From the material cut through by the tunnel, which was examined by King,<sup>1</sup> of the Georgia geological survey, the rock was found to be an altered peridotite, made up of small grains of chrysolite surrounded by actinolite, and containing many grains of magnetite. It may be that the original of this rock was the peridotite amphibole-pierite.

All the work that has been done at this mine has been entirely within the formation, and the best results would be obtained near the contact of this rock with the surrounding country rock.

*Foster mine.*—This mine, which is located in the northeastern part of Towns County, Ga., just over the North Carolina line, has been described with the other mines occurring in this vicinity under the head of "Corundum in North Carolina," on page 60. The corundum occurs in a quartz-schist, and the property is owned by the Corundum Mining and Manufacturing Company, of Philadelphia, Pa.

---

<sup>1</sup> Bull. Geol. Survey Georgia No. 2, 1894, p. 93.

## SOUTH CAROLINA.

In the northeastern part of York County, from 3 to 4 miles west of the Catawba River, on the land between Allison and Crowder creeks, corundum has been found in a belt about 200 to 300 yards wide which skirts along the western slopes of Nannies Mountain. This locality is about 12 miles northeast of Yorkville, S. C., and 25 miles southwest of Charlotte, N. C.

Mining operations have been carried on at two distinct portions of this belt, one a mile north of the summit of Nannies Mountain, on the property of Alexander Rickard. The work done here consists of a shaft about 35 feet deep, from which several drifts have been run, which penetrate what is probably a light-gray granite, but it is much decomposed and of a sandy constituency. The only solid material encountered were irregular masses of black cleavable corundum associated with muscovite mica. In the surrounding fields float corundum ranging in size from small particles to masses of several pounds in weight are abundant, and many tons of this have been picked up and shipped.

A little to the west of the south end of Nannies Mountain, about  $1\frac{1}{2}$  miles from the Rickard mine, there is a similar occurrence of corundum. There have been a number of shallow cuts, ditches, and pits made in prospecting for corundum, but apparently none was found in place. The corundum that was found is often wrapped in mica.

The mode of origin of this corundum has not been determined, for up to the present time the exact nature of its occurrence is not definitely understood, as no exposure of the corundum can be seen which shows its relation to the rock in which it occurs. Neither can it be stated whether it is to be found in quantity.

## PENNSYLVANIA.

The corundum in this State, so far as can be learned, is all associated with the serpentine rocks in Chester and Delaware counties and occurs near the contact of this rock with the gneiss. Considerable feldspar (plagioclase) similar to that described from the Big vein at Buck Creek, N. C., is usually crystallized out with the corundum.

Corundum has been found more abundantly near Unionville, in Newlin Township, Chester County. It is found here in a mass of serpentine rock, with an average width of about 800 feet and a length of 1 mile. A number of tons of corundum have been obtained from this mine, but during the last ten years little or no work has been carried on here. Associated with the corundum are tourmaline and spinel.

## MONTANA.

Most of the corundum that has been found in Montana has been of the sapphire variety, but at one locality near Bozeman, Gallatin



A PERIDOTITE FORMATION AT LAUREL CREEK GEORGIA.



B DUNITE VEIN OF CORUNDUM AT LAUREL CREEK, GEORGIA.



County, a variety has been found that may upon development prove to occur in commercial quantity. While no tests have been made to determine the abrasive quality of this corundum, preliminary fire tests have been made which indicate that it is suitable for use in the manufacture of the vitrified wheel. Then, again, the percentage of corundum in the ore, simply judging from the hand specimens, is high enough to make this a workable ore if in sufficient quantity. A description of the rocks in which the corundum occurs is given on page 30.

#### EMERY.

Until recently the only emery known to occur in the United States was that at Chester, Mass., and Peekskill, N. Y., the principal mining being done at the latter place. Emery has now been found in North Carolina in a very promising prospect. As is stated on page 9, emery is a mechanical mixture of corundum and magnetite, or sometimes hematite. From its striking resemblance to iron ore, especially where it is a mixture of corundum and magnetite and is therefore magnetic, both the deposits at Chester and Peekskill were first worked as iron ores, and it was not for some time that their real nature and value were understood. Since then the deposit at Chester has been worked continuously and extensively.

Spinel is sometimes associated with the emery and increases in amount until it is largely in excess of the corundum, and the ore passes over into what might well be called a "spinel emery."

#### MASSACHUSETTS.

The only deposit of emery that has been found in this State is in the vicinity of Chester, where the emery vein has been traced for nearly 5 miles. The vein is first encountered about 2 miles northwest of the village of Chester, in a ledge that projects into Westfield River from its left bank. The vein can be followed almost continuously along the line of the strike—south to a little east of south. It extends across the east slope of Gobble (North) Mountain, drops down into and crosses the narrow valley of Walker Brook, and then rising, it crosses South Mountain and can be followed for over 2 miles to the south. The map (fig. 13) shows the general position of this emery vein, the places that have been opened along it, and the location of the different emery mills. The emery occurs in an amphibolite, which has been described on page 23.

Beginning at the southern end of the vein the first work has been done about half a mile north of where the vein disappears, at what is known as the Wright mine. About twenty years ago rather extensive mining was being carried on here, the work consisting of an open cut nearly 1,400 feet long that was worked to a depth of 6 feet at its southern end and about 30 feet at its northern, with probably an

average depth of 20 feet for the entire distance. Emery varying in width from 3 to 20 feet was encountered throughout nearly the entire length of the cut.

This mine was reopened in 1899, a shaft 87 feet deep having been sunk on the vein near the southern end of the cut and drifts run out from this. Margarite is the most conspicuous accessory mineral, and specimens that can rarely be excelled have been found here.

Continuing nearly half a mile to the north on the vein and near the top of the mountain is the Melvin mine. There is a shaft here 40 feet deep, from which drifts are being run. This shaft is but 1,250 feet from the head of the upper tunnel of the Old mine, the next

one to the north. It is in this Old mine that the most extensive work has been done. Fig. 14 is a cross section of its underground workings. The mouth of the lowest tunnel is but 8 feet above Walker Brook and 75 feet to the south of it. As is seen from the diagram, the emery does not occur continuously throughout the vein, but in pockets or chimneys which dip into the vein about  $30^{\circ}$  N. From the work already done these seem to hold this direction rather constantly, so that the pockets can be approximately located at a given depth.

It was in the first chimney of emery (see map, fig. 13)

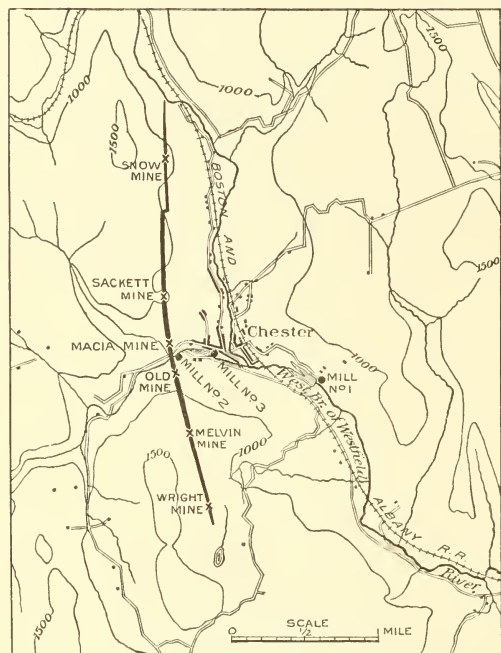


FIG. 13.—Map showing the location of the emery deposit at Chester, Mass.

that the beautiful specimens of diaspore, for which this mine is noted, were found.

North of Walker Brook and about 500 feet from the Old mine is the Macia mine, where a small amount of surface work has been done. Near the head of a small ravine a tunnel was started on the west of the vein to intercept it, but work was discontinued before the vein was reached.

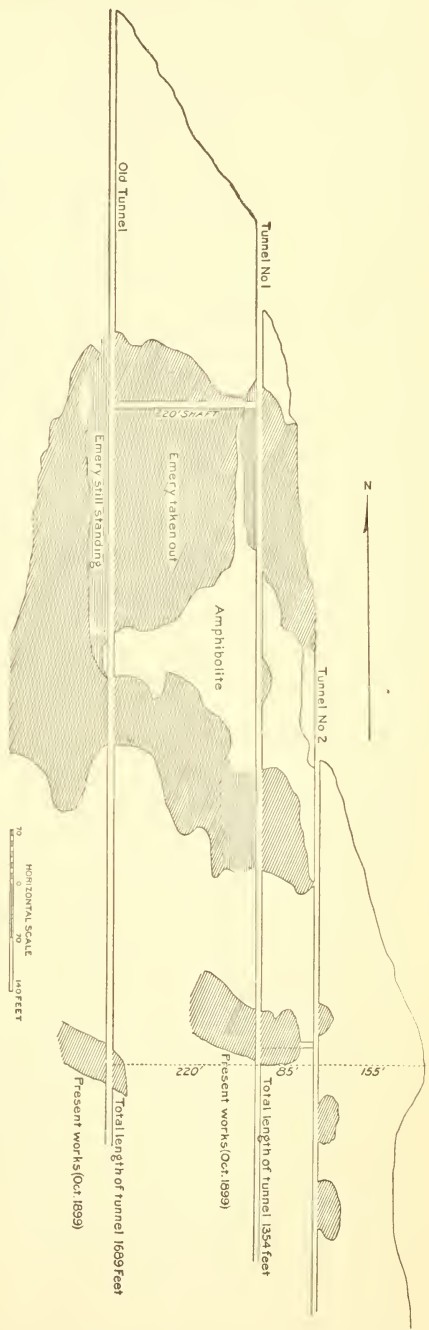
The next opening is near the highest point of the vein on the eastern slope of Gobble (North) Mountain, about three-fourths of a mile north of the Macia mine, and is known as the Sackett mine. At this part of the vein there was a considerable quantity of magnetite

that was practically free from corundum and was mined as an iron ore. This mine was worked very extensively over twenty years ago, but had been abandoned until 1899, when it was reopened. The old works were near the highest point of the vein, on the slope of the mountain, and were worked for about 30 feet. The new work was started 117 feet below the mine, and a tunnel from the east side was run 114 feet to the vein. When this was reached a shaft and tunnels were started. At this mine the corundum occurs in what might be called porphyritic crystals of a bronze color, which are from 5 to 15 mm. across. Here blue and white masses of corundum weighing several pounds have been found, and small, well-formed blue crystals are also frequent. A little north of this mine, in an old opening, a cross vein of chlorite was encountered which carried a great many almost perfect cubes of pyrite and radiating groups of black tourmaline.

The last opening on the vein where there has been any work is at the Snow mine, over a mile north of the Sackett mine. A small open cut was made that exposed the vein, 3 feet in width. Between these two mines and also from the Snow mine north to the river the vein can be followed almost continuously.

While the vein can be followed nearly the whole distance, the emery does not occur throughout its entire length, for it is

FIG. 14.—Cross section of the Old mine at Chester, Mass., showing the amount of emery taken out to April, 1899.



often in a series of pockets that are frequently connected with each other along the strike by a thin streak of chlorite and have a general dip in the vein of about N. 30°. In the direction of the dip, however, the emery is more or less continuous. The width of the vein varies from a few feet to 10 or 12, with an average width for the emery of about 6 feet. This is the most extensive deposit of emery known in this country.

Emery has also been discovered in the vicinity of Huntington, Mass., but no development work has as yet been done.

#### NEW YORK.

The emery deposits of this State occur associated with the norite rocks in Westchester County that have been described on page 26. Deposits of magnetite and emery have been found at a number of places 3 to 4 miles southeast of Peekskill. These deposits vary considerably in character, some being a nearly pure magnetite, others containing magnetite and spinel, and still others magnetite, spinel, and corundum. Those within a mile north and northeast of Crugers Station have been worked for iron ore, while those worked for emery are in the southeastern part of Cortland Township. The principal openings have been made on a ridge running north from Colabaugh Pond and it is here that the ore has been mined. While the iron ore and emery appear to be very rich it was found upon examination that there was more or less of a dark-green mineral mixed with magnetite, and this mineral was shown by Williams<sup>1</sup> to be the pleonaste variety of spinel. There is also considerable spinel in the emery, and even when this is quite abundant it can not be distinguished in the hand specimens from that in which there is almost none of this mineral.

At the emery deposits in the southeastern part of Cortland Township the percentage of corundum varies considerably at different openings, and it is sometimes observed in small blue, white, and colorless crystals. Associated with most of the corundum there is spinel, and considerable of the ore that has been mined for emery has contained little or no corundum and has been made up of magnetite and spinel. An ore of this sort would have most of the requisite properties of a true emery except the high degree of hardness due to the corundum; and when made up into a wheel it would not have the cutting efficiency of a true emery wheel. The spinel, which is 8 in hardness (corundum being 9), would play the same part in this ore as corundum in the true emery, and while not so hard as corundum it has the cutting qualities which would give the ore considerable value as an abrasive. For many purposes wheels made from this could be used fully as well as emery or corundum wheels and for some purposes they might be used to better advantage. The spinel would not interfere at all in the manufacture of a vitrified wheel.

<sup>1</sup> Am. Jour. Sci., 3d series, Vol. XXXIII, 1882, p. 194.

Some of the ore that has been mined here carries a very high percentage of garnet.

The analyses that have been made of this ore all show a high percentage of alumina, which was to be expected, as the spinel is an alumina mineral,  $(\text{MgFe})\text{O} \cdot \text{Al}_2\text{O}_3$ , containing about 50 per cent of this oxide. An error is very often made in judging the percentage of corundum in an ore by calculating as corundum the total percentage of alumina obtained in a chemical analysis, which would represent, however, the alumina contained in all the aluminous mineral components of the ore.

Some of the ore at these mines is undoubtedly a true emery, but a considerable portion of it is a mixture of spinel and magnetite, which, while not a true emery, will make a useful abrasive. This whole ore body might be called a spinel-emery.

From what has been said regarding the occurrence of the emery in these Peekskill deposits, their pockety nature is what would be naturally expected and this has been characteristic of all the mining that has been done in this district.

The Jackson Mills Company, of Easton, Pa., is now the largest miner in this section. It has leased the emery deposits on the land of Isaac McCoy, 3 miles southeast of Peekskill. Its principal work is on the summit of a hill about one-half mile south of McCoy's house and consists of an open cut 40 to 50 feet deep, 40 feet long, and 12 to 20 feet wide. The emery ore is from 4 to 6 feet wide, but is broken up by bands of serpentine and chloritic rocks. In some of the ore the corundum is very distinct, occurring in elongated bluish white crystals up to 5 mm. long. This ore is very free from garnet.

Another deposit of emery has been encountered 50 feet below the summit, and still another 25 feet farther down. No mining has been done at either of these localities.

The ore is hauled by teams to Peekskill, where it is shipped by rail to Easton, Pa.

On a hill 1 mile east of the McCoy mine H. M. Quinn, of Philadelphia, Pa., has mined on the land of John H. Buckby. Pockets of emery were encountered on the summit of the hill and at a number of points on its western slope, but they soon pinched out. About 50 feet below the summit a face of rock 15 to 20 feet high and 40 feet across has been exposed. The only emery seen here is the remnant of a pocket.

As far as could be learned the emery deposits of the Tanite Company of Stroudsburg, Pa., are also leased. They are on the lands of Henry Heady, Oscar Dalton, and David Chase, and are for the most part similar to the deposits just mentioned. The ore on the land of Henry Heady is composed largely of garnet, and a considerable portion of it has been shipped by the Tanite Company to their mill at Stroudsburg.

## NORTH CAROLINA.

While corundum has been known to occur in quantity in this State for over thirty years, emery has until recently only been known from one locality, and here the quantity was not apparently sufficient to be worthy of any development. This deposit has been described by Genth<sup>1</sup> as occurring at the McChristian place, 7 miles south of Friendship, Guilford County.

During the past few years emery has been found in Macon County in what appears to be considerable quantity. Nothing definite can be stated regarding the rock in which it occurs, as it is greatly decomposed as far as it has been exposed by the excavations. It does have, however, very much the appearance of a decomposed basic magnesian rock. There are a number of small outcrops of this saprolitic rock about 5 miles southwest of Franklin, the county seat, and emery in varying quantity occurs at all of them.

These outcrops, as far as could be judged, are isolated and in no way connected with one another. They are lenticular in form and but a few hundred feet wide, the longer axis being sometimes two or three times this. While the general direction of the strike of these outcrops is nearly the same, they are not in even an approximate line as regards one another. For nearly 15 miles south of these and following the valley of the Little Tennessee River small isolated outcrops of peridotite are numerous. The country rock through which these have forced their way is a hornblende-gneiss.

Considerable mining was done two years ago by Dr. H. S. Lucas, of Franklin, at the Fairview mine near North Skeener Gap, about a hundred tons of ore having been taken out and cleaned. The vein has been tapped at intervals for a distance of nearly 200 feet, good emery being encountered at each opening. All the work done was near the summit of Fairview Knob.

One mile N. 25° W. of the Fairview mine, on the southwest slopes of Dobson Mountain, another opening has been made for emery in an outcrop of the same rock on the land of J. A. Waldroop. A vein of emery ore was uncovered here that was 15 feet wide. No mining has been done here, all the work being in the nature of prospecting.

Emery has been found in similar outcrops on the lands of William Mann, three-fourths of a mile south, and of James Ledford, one and one-fourth miles S. 30° E. of the Fairview mine.

Preliminary fire tests were made upon the cleaned product of this ore, which proved it to be well adapted for use in the manufacture of the vitrified wheel.

## METHODS OF MINING CORUNDUM.

In considering the methods used in mining corundum, it must be borne in mind that up to the present time it has been obtained in quan-

<sup>1</sup> Bull. U. S. Geol. Survey No. 74, 1891, p. 30.

tity only where it has been associated with peridotite rocks. These rocks, as will be shown later, present certain difficulties which, if not overcome, will cause considerable delay and danger in mining. The emery occurring in amphibolite presents these difficulties in only a slight degree.

Nearly all of the peridotite formations in which the corundum deposits occur are bold outcrops on the mountain sides and hilltops, having almost perfect natural drainage. At all the localities where there has been no mining the little prospecting has been usually by means of open cuts supplemented by tunnels. While at first mining by means of cuts may seem to be the most advantageous, it is soon found to be the cause of considerable extra expense. These cuts, or any other openings made over the surface of the peridotite, offer a much greater opportunity for surface water and frost to penetrate the mass of the rock formation. These rocks are more or less seamed or cracked, usually to the depth that alteration can extend, and thus offer opportunities for the infiltration of water. As most of the alteration products of this peridotite formation are slippery hydrous magnesium minerals, such as serpentine and talc, and as these are developed in the seams and cracks of the peridotite, anything that is done to disturb them will make them very liable to slip. At the Corundum Hill mine there are large masses of peridotite that have become loosened and gradually slipped down and closed up some of the tunnels, and there is constant danger that fragments of the rock will fall into the cuts and some of the tunnels. At the Laurel Creek mine, a mass of peridotite with soil, etc., nearly a 200-foot cube, has become loosened and slipped downward, effectually closing up the tunnel and shaft of the Big vein.

In mining corundum associated with peridotite rocks it is therefore advisable not to break the surface of the formation any more than is absolutely necessary and to do no work at all along the contact by means of open cuts, but to confine the mining to a system of tunnels and shafts. This method of mining will be found the cheapest in the end. Then, again, all the tunnels and shafts should be well timbered and the mine kept as thoroughly drained as possible.

A large amount of the material that must be handled is easily worked with pick and shovel, as it consists of the crystals and fragments of corundum in the zone of chlorite and vermiculite. In those veins in which the corundum is associated with feldspar, as at Laurel Creek and Buck Creek, and those where there is considerable amphibole or enstatite, as at Corundum Hill, blasting is necessary. Most of the corundum deposits in peridotite are so located that there need be but little hoisting of the ore for some time. By drifting from a shaft at the upper end of a tunnel that has been run into the vein at the lowest level possible the ore can be removed with a minimum of hoisting and the mine will be kept dry.

If the mill is located some distance from the mine and a line of

sluice boxes can be built, the more or less finely divided ore may be carried to it by means of these. In this way the ore is partially cleaned by the time it reaches the mill. This is the method employed at the Corundum Hill mine.

Where the corundum occurs in a gneiss, quartz-schist, or syenite, there should be no difficulty in mining by means of open cuts.

#### METHODS OF CLEANING CORUNDUM.

The difference between the commercial product and the ore as it comes from the mine is that the latter has been freed as far as possible of all impurities, so that the resulting product is or should be nearly pure corundum or emery. Most of the impurities are easily removed by conveying the crushed ore into boxes through which a stream of water runs, which is so regulated that the corundum readily settles to the bottom of the trough and the lighter minerals are carried off. Before this, however, the crushed ore is sieved, and all that will not pass through a No. 12 screen is recrushed and passed between rollers until it is reduced to the desired size. This washing process will remove only the impurities that are entirely separated from the particles of corundum, but there are usually some of the impurities attached to the particles or grains that have to be removed by another process. The product is passed through a machine known as the screw or scouring machine, in which there is a coarse worm similar to the screw conveyer. This grinds out almost all of the impurities, and these are separated by again subjecting them to the washing process. The final impurities are separated from the particles of corundum by means of a machine called the "muller" or "chaser" (see Pl. XIV). The principle of this is to cause each grain of corundum to rub against another and thus wear away the adhering foreign substances. The machine consists of a shallow tub, in which are two heavy wooden rollers which move around its circumference. The freshly ground corundum on being thrown into these tubs is kept constantly stirred up and then pressed down by the rollers being passed over it. In this way the scouring motion is kept up between the grains. The impurities are thus gradually worn away and are carried off by a stream of water that flows continually through the tub. The corundum in the tub is kept stirred up by men with hoes or by plow-shaped iron blades in front of the wooden rollers. It usually requires from four to eight hours, according to the nature of the impurities that are attached to the corundum grains, to obtain a clean product.

There are two methods of drying this product, by either of which it is removed from the mullers and allowed to lie overnight on inclined floors. By one method this product is conveyed by elevator belts to the second floor of the mill and dropped vertically for a distance of 20 to 30 feet down the stack of a furnace. At the bottom it strikes an



A CORUNDUM MILL AT CULLASAGEE, MACON COUNTY, N. C.



B INTERIOR VIEW OF CORUNDUM MILL AT CULLASAGEE MACON COUNTY, N. C.



inclined surface that is just above the flames of the furnace and slides down this surface into an iron box. By the other method the wet product is thrown in at the upper end of an iron cylinder, open at both ends, which revolves about a coil of steam pipes. One end of the cylinder is lower than the other, and the wet mass is alternately carried up by the revolving cylinder and dropped on the hot coil of pipes, and so gradually worked toward the lower end, where it is caught in a hopper and conveyed by elevator belts to the sizing room. Here it is automatically screened to the various sizes.

On Pl. XIV, *A* and *B*, are views of the exterior and interior of the corundum mill at Cullasagee. In the foreground of *B* are the boxes in which the ore is first washed and just beyond these are the mullers.

Only within the last few years has any attempt been made to improve the methods of concentrating and cleaning corundum. There are now a number of companies that have installed complete concentrating mills, similar to those used in concentrating gold ores, but modified to suit corundum ore. While all are using jigs for the coarser sizes of the crushed ore, some are using Frue vanners and others Bartlett or Wifley tables for the finer sizes. This method works very satisfactorily for concentrating the corundum, and if, during the crushing and rolling of the ore, the corundum is largely separated from the associated minerals, a nearly cleaned product is obtained. It is necessary, however, to subject the larger part of the concentrates to some process similar to that performed by mullers, to free the grains of corundum from other minerals attached to them.

A new machine—the Hooper pneumatic concentrator—can also probably be used to advantage in concentrating corundum ores.

Any other minerals that will be likely to remain with the corundum in the concentrates, as garnet, pyrite, etc., can undoubtedly be separated by means of the Wetherill magnetic concentrator. Unless these minerals are unattached to the particles of corundum there will be a considerable loss of corundum by this separation.

### USES OF CORUNDUM.

Corundum is used for only two general purposes, as gems and as an abrasive.

The varieties of corundum that are of value as gems have been described on page 39, and the many uses that are made of the cut stones in the jewelry trade are too well known to need more than a passing notice here. One use of the corundum gem that is perhaps worthy of notice is in supplying jewels for watches. In a recent notice from the Swiss agency of precious stones for watches, Aarburg, Switzerland, it said that 75,000,000 watch jewels are required annually. With the increase of production of gem corundum in this country a

great deal of the smaller fragments could and should be utilized in the manufacture of watch jewels.

Both corundum and emery are used in the manufacture of abrasive materials, and these are on the market in three forms, as wheels and blocks of various shapes and sizes, as emery paper, and as grains or powder. The last two need no further explanation, but a description of the first is of importance.

The shapes of the corundum and emery wheels and bricks or stones are extremely varied, being adapted to all kinds of grinding. The principle of these wheels is the same as that of the rotary files, and as the points of a file become dull from using, so also do the grains or points of the emery and corundum in the wheel. In making a wheel it is necessary, therefore, to make it of such a temper or grade that when these grains become dull or rounded they will fall away or will be readily removed by a truing tool, leaving fresh, sharp grains exposed. The grade of a wheel depends upon the character of the work for which it is to be used, and the bond should be such that it will wear away a little faster than the corundum or emery, and thus always leave the sharp edges ready for cutting. The greatest economy is effected when the bond does not wear away until the grains of emery or corundum have become rounded or dulled, thus permitting the wheel to do its greatest amount of work.

Before leaving the factory all wheels should be thoroughly tested to a higher strain than that to which they are to be subjected in actual use; as the wheels have to be run at a very high velocity in order to secure the greatest efficiency, there is at times but little reserve strength, and a sudden blow will often cause them to fly to pieces.

To give an idea of the number of different wheels that the larger emery-wheel companies are prepared to make, I can not do better than to mention what I saw and what was told me at the Norton Emery Wheel Company, of Worcester, Mass. The wheels are manufactured for the special work for which they are intended, and vary in shape, in bond, and in grain of corundum. The sizes of corundum that are used are Nos. 12, 14, 16, 20, 24, 30, 36, 40, 50, 54, 60, 70, 80, 90, 100, 120, 150, 160, 180, 200, and 6 grades of flour corundum. The bond has 26 degrees of hardness, represented by the letters of the alphabet, although a bond is seldom used softer than E or harder than M. There are 408 different sizes of circular wheels, so that the different grades of wheels possible are almost unlimited.

There are three types of wheels known to the trade, the vitrified, chemical, and cement, the names being derived from the process by which they are manufactured. In the manufacture of all, the corundum or emery used is in grains of uniform size, but varies with the grade of wheel that is to be made. The vitrified wheel is the most important and most generally used, although for some work one of the

others is preferable, and for very large wheels the chemical is especially adapted.

#### VITRIFIED WHEEL.

In the manufacture of this wheel more care is necessary in the selection of the corundum, for in the vitrification of the bond the foreign minerals containing water are very likely to cause the wheel to burst. The corundum grains are mixed thoroughly in a paste of prepared clay and other fluxes, and the mixture is then poured into paper molds and set aside in a drying room until hard enough to be readily handled. When the molds are sufficiently dry, they are subjected to a dressing or trimming process and shaped to approximate dimensions on a potter's wheel or shaving machine, and are then further dried.

The excess of mechanical water having evaporated, they are then ready for the kilns. The kilns are cone shaped and the inside measurements vary from 12 to 20 feet in height and 10 to 18 feet in diameter. When the kiln is filled the entrance is closed and sealed and the fires are started. The temperature is allowed to rise slowly, until all the water of mechanical admixture and of crystallization in the foreign materials is driven off, when the temperature is raised to about 3,000°, or to a white heat, this heating process requiring several days. Where the foreign minerals mixed with the corundum contain water of composition that is driven off only at a very high temperature, the wheels are apt to be broken by this water coming off when the temperature of the kiln is raised to the fusing point of the clay. The clay and other fluxes fuse and form a porcelain setting for each grain or fragment of corundum, which makes a very strong bond. The kilns are allowed to cool very slowly, several days being required for this. The kiln is then opened and the wheels are brought to a lathe, called the "truing machine," where they are turned to the exact dimensions desired, the hole is bushed to the exact size, and the wheel is then trued and balanced ready for shipping.

The heat necessary for the fusion in making the vitrified wheel apparently has no effect upon the corundum beyond a partial decolorization and the expulsion of the slight percentage of water in the corundum.

#### CHEMICAL WHEEL.

In this process, which is also called the silicate process, silicate of soda is used as the binding material. The silicate is thoroughly mixed with the emery or corundum and some drying material and tamped into molds. It is then subjected to an "oven" heat for twenty-four hours, after which it is removed and finished according to the method described above for the vitrified wheels after they are removed from the kilns. Wheels have been made by this process that were over 2,000 pounds in weight.

## CEMENT WHEEL.

In the cement wheel, shellac, rubber, linseed oil, and other substances are used as the binding material. This makes a soft wheel that is well adapted for roll and surface grinding when made with shellac, and for saw gummers and thin wheels when made with oils.

Although an examination of a corundum property may show the existence of considerable quantity of the mineral, no mining should be undertaken until satisfactory tests have been made upon the corundum to prove that it has those properties that will make it of value as an abrasive.

The value of a corundum deposit as an ore for abrasive purposes depends upon that property of the mineral which enables it to retain a sharp edge, known as a cutting edge, when it is crushed to grains. All corundums do not have this property, and while many exhibit this in the first stage of the crushing, the finer fragments and grains do not. This is more apparent when the corundum has been made into a wheel, for when first used the wheel may do good work, especially if it is a coarse-grained wheel, but as it wears away, the grains of corundum become rounded, instead of breaking to a cutting edge. In estimating the value of a corundum deposit, it is therefore very essential to determine the abrasive qualities of the corundum. Neither a chemical analysis nor a superficial examination of a corundum ore will determine its cutting qualities, and this can be obtained only by making the corundum into a wheel and testing it.

In estimating the value of an ore it is also necessary to determine to what degree of purity it can be cleaned, or what percentage of the commercial product will be corundum, and also what will be the nature of the foreign minerals. A foreign mineral will always be softer than the corundum, and will to a certain extent reduce its abrasive power. Beyond this, the presence of a small amount of foreign mineral does not materially affect the value of the corundum for making a cement or chemical wheel, but is often the reason for discarding it in manufacturing a vitrified wheel, on account of the low fusibility of the foreign substance. Garnet is perhaps the most objectionable mineral in a corundum ore, it being very difficult to separate it from the corundum, because the specific gravity of the two is nearly the same. Corundum containing even a little of the garnet can not be used in the manufacture of the vitrified wheel.

## OTHER USES.

An attempt has been made to use corundum as a source of aluminum, but on account of its refractoriness and the percentage of ferric oxide and silica that it often contains, and on account of the cost of the ore, this use has not been found feasible.

The late Mr. Alfred E. Hunt, of Pittsburg, Pa., made the following statement:<sup>1</sup>

The real difficulty which we find in the use of corundum for this manufacture is the cost of the raw material as compared with that of native bauxites. In this item we include not only the price of the corundum as it has been offered to us, but also the expense of grinding it to an impalpable powder, which must be done before it can be used directly in the manufacture of aluminum, and the cost of preliminary chemical treatment for purification—which latter operation, however, is also required for bauxite.

Corundum has also been used as the source of the aluminum in the manufacture of aluminum-copper and aluminum-iron alloys. In the manufacture of these the corundum, without undergoing any previous treatment, was charged into an electric furnace with a mixture of carbon and copper or carbon and iron, according to whether aluminum bronze or ferro-aluminum was desired. Since 1890, however, when alumina began to be manufactured at a comparatively low price, this artificial oxide has been used in the place of the corundum.

#### CORUNDUM LOCALITIES IN THE UNITED STATES.

Under this head are included practically all the localities in the United States at which corundum has been found, and if they have been described under the heading "Distribution of corundum" they are simply mentioned here. Regarding the other localities, the mode of occurrence is given in most cases, and also some idea of the extent and character of the corundum.

This list is probably not complete, but it represents all those localities that I have visited and those of which an authenticated record could be obtained. It is taken up alphabetically by States.

##### ALABAMA.<sup>2</sup>

*Dudleyville*.—Between this town and Perry Mills, Tallapoosa County, corundum has been picked up at a number of places in the soil, but none has been found in place. Peridotite rocks have been found in the vicinity, and it is not at all improbable that the corundum was derived from these rocks.

*Hanover*.—Corundum has been found sparingly in Coosa County in the vicinity of this town.

##### CALIFORNIA.

*Plumas County*.—An interesting occurrence of corundum has recently been observed in the vicinity of Meadow Valley. Cutting the serpentine rocks of the eastern slope of Spanish Peak at an elevation of about 4,100 feet, and  $1\frac{1}{2}$  miles west-northwest of the Meadow Valley post-office, is a series of white coarse-grained dikes that are

<sup>1</sup> Trans. Am. Ins. Min. Eng., Vol. XXVIII, 1898, p. 875.

<sup>2</sup> Geol. Survey Alabama, Report, 1875, p. 85.

composed of 84 per cent of oligoclase and 16 per cent of corundum. The corundum is in crystals up to 2 inches in length and 1 inch in diameter, the general habit being pyramidal, and it is distributed rather irregularly through the groundmass of feldspar. This is a further illustration of the differentiation of a rock magma, supersaturated with alumina which has crystallized out as corundum. It is still uncertain whether these deposits of corundum will prove to be of commercial importance.<sup>1</sup>

#### COLORADO.

*Chaffee County.*—Corundum crystals have been found at the Calumet iron mines in the mica-schists at their contact with intrusive dikes of diorite. R. C. Hills, geologist to the Colorado Fuel and Iron Company, writes that the ore occurs in a band of rock 6 inches to 2 feet thick that has been followed for a distance of 500 feet, and that it averages 40 per cent of corundum.

#### CONNECTICUT.

*Litchfield.*—Corundum was found here associated with tale and pyrite in a mass of blue cyanite. Only surface specimens were found.

*Norwich.*—In the vicinity of this place corundum was found sparingly with sillimanite.

#### DELAWARE.

Corundum has been found in this State in the serpentine rocks near the Pennsylvania border. The only locality definitely known is near Chandlers Hollow, in Newcastle County, about 2½ miles south of Concord, Delaware County, Pa. It has been found only in small quantity.

#### GEORGIA.

*Acworth.*—Seven miles southwest of Acworth, Cobb County, there is a large peridotite formation which is entirely within Paulding County. From a pit sunk within this formation about 1,000 pounds of corundum were taken out. It is of poor quality, but makes handsome mineral specimens.

*Bell Creek mine.*—This mine is 4 miles north of Hiwassee, Towns County, and the corundum, mostly of a pink color, occurs in a peridotite. The work done consists of a pit 12 feet square by 12 feet deep. Only a small quantity of corundum was found.

*Centralhatchee.*—At this place, which is in Heard County, grayish, white, and blue corundum has been found in a matrix of hornblende, which is associated with basic magnesian rocks.

*Douglas County.*—Blue corundum in a pale greenish cyanite.

*Foster mine.*—The corundum occurs in quartz-schist. (See p. 60.)

*Gainesville.*—Beautiful specimens of red corundum have been found in the peridotite formation 1 mile east of Gainesville, Hall County.

<sup>1</sup> A. C. Lawson: Am. Geologist, Vol. XXVII, 1901, p. 132; J. A. Edman, letters from.

*Habersham County.*—Corundum has been found as surface specimens at a number of localities in this county, and at one place in the peridotite formation. There have been no developments and there are no indications of any quantity.

*Hamilton mine.*—The corundum occurs in a peridotite formation about 5 miles north of Young Harris, Towns County. No large quantity has been found.

*Hog Creek mine.*—This mine is 2 miles a little south of west of Hiwassee, Towns County, but it lacks development. The corundum is associated with peridotite, and is pink, blue, and white.

*Laurel Creek mine.*—In peridotite. (See p. 63.)

*Monroe.*—Four and a half miles from Monroe, Walton County, on the farm of George W. Breedlove, black corundum has been found associated with peridotite rocks. Some little prospecting done here has been within the formation and some near the contact.

*Pine Mountain, Rabun County.*—In peridotite. (See p. 63.)

*Porter Springs.*—One mile southeast of this place (in Lumpkin County) corundum has been found in an amphibolite, but there is no quantity.

*Powder Springs.*—There is a considerable outcrop of peridotite in Cobb County, in the vicinity of Powder Springs, which offers a promising place for prospecting. A small vein has been opened on the W. B. Turner farm.

*Rabun Gap.*—Several pounds of corundum have been obtained from the Beavett mine; it occurs in a peridotite rock.

*Teltonville.*—One mile north of this town, in Forsyth County, surface specimens of corundum were found which evidently originated in the quartz-schists of this region.

*Stone mine.*—This mine, which is in the same general formation as the Track Rock mine (see p. 65), is in Rabun County. Only a little development has been undertaken and the prospect that the deposit may be valuable is not very favorable.

*Thomaston.*—Seven to 8 miles southwest of Thomaston, Upson County, considerable corundum has been found on the surface at the old Kelly farm. Some of the specimens of the corundum in the matrix indicate that it was derived from a mica-schist.

*Track Rock mine.*—In peridotite. (See p. 65.)

*West Point.*—A short distance northeast of this town (in Troup County) corundum has been found sparingly in a narrow strip of peridotite. Apparently no large quantity.

#### MARYLAND.

Corundum has been reported to occur in the vicinity of Whitehall, but no definite information can be obtained that any has been found here beyond a stray surface specimen.

## MASSACHUSETTS.

*Chester*.—Emery in amphibolite. (See p. 67.)

*Huntington*.—Emery in amphibolite. (See p. 70.)

*Pelham*.—Corundum in saxonite. (See p. 19.)

## MONTANA.

*American Bar*.—The lowest bar on the Missouri River on which sapphires have been found. (See p. 47.)

*Cottonwood Creek*.—In the gravels of this creek greenish-colored sapphires have been found. (See p. 51.)

*Dana Bar*.—A bar in the Missouri River, in the gravels of which sapphires have been found. (See p. 47.)

*Eldorado Bar*.—Sapphires in the gravel. (See p. 47.)

*Emerald Bar*.—The highest bar on the Missouri River in which sapphires have been found. (See p. 49.)

*French Bar*.—Sapphires have been found in a small dike of andesite. (See p. 47.)

*Gallatin County*.—Corundum in syenite. (See p. 66.)

*Maggie Gulch*.—Pale-greenish sapphires have been found in the gravel. (See p. 47.)

*Metropolitan Bar*.—Sapphires occur in the gravels. (See p. 49.)

*Missouri River bars*.—In the various bars along the Missouri River, 18 miles east and northeast of Helena, sapphires have been found in the gravel. (See p. 47.)

*Rock Creek*.—All colors of sapphires are found in the gravel of this creek. (See p. 50.)

*Ruby Bar*.—Sapphires occur in an andesite dike. (See p. 47.)

*Spokane Bar*.—A bar of the Missouri River where the most mining has been done for sapphires that occur in the gravels. (See p. 48.)

*Yogo Gulch*.—Blue sapphires occur in a dike of minette. (See p. 52.)

## NEVADA.

*Silver Peak*.—Corundum has been reported from near this place.

## NEW JERSEY.

*Franklin Furnace*.—A small pocket of corundum has been found here associated with dolomitic limestone.

*Newton*.—Blue and white corundum occurs in a whitish feldspar near the contact of the granitic rock and white limestone.

*Vernon*.—Small pockets of corundum in limestone, but not in great quantities. (See p. 36.)

## NEW YORK.

*Amity*.—Blue and white corundum has been found in the limestone near Amity and Warwick, Orange County. Does not occur in large quantity.

*Peekskill.*—A short distance east of Peekskill emery is found in basic magnesian rocks in some quantity. (See p. 70.)

#### NORTH CAROLINA.

*Acme mine.*—This mine is located about three-quarters of a mile west of Statesville, Iredell County. The corundum occurs in crystals in an amphibolite.

*Addie.*—Crystals of corundum have been found sparingly associated with the peridotite rocks in the vicinity of Addie, Jackson County.

*Bad Creek mine.*—Corundum associated with peridotite. (See p. 62.)

*Bakersville.*—Corundum crystals have been found sparingly in the gneiss at William Bowmans, three-fourths of a mile west of Bakersville, Mitchell County.

*Behr mine.*—This mine is near Elf post-office, on Shooting Creek, Clay County. Pink and white corundum have been found associated with peridotite rocks.

*Belts bridge.*—Crystals of black corundum occur in an amphibolite 8 miles northwest of Statesville, Iredell County, on the Hunter farm.

*Belts Gap.*—Corundum in splendid grayish-white crystals that are translucent are found in the gneiss to the south of the gap in Jackson County. Garnet also occurs in the gneiss.

*Blue Ridge properties.*—Corundum occurs in gneiss. (See p. 59.)

*Brockton mine.*—Corundum occurs in the peridotite. (See p. 61.)

*Buck Creek mine.*—Also known as the Cullakeence. Is in a peridotite formation. (See p. 58.)

*Burnt Rock mine.*—In a peridotite formation. (See p. 61.)

*Caler Fork.*—Ruby mine, the crystals being found in the gravels of the creek. (See p. 40.)

*Caney Fork.*—Two miles above the mouth of this creek, in Jackson County, corundum is found in the chlorite-schist in considerable quantity. At many points along this creek and its tributaries corundum has been found in the chlorite-schists and in gneiss near these schists, as at the mouth of and also 2 miles up Chastains Creek and on Shoal Creek Mountains on the West Fork.

*Carpenters Knob.*—Along the ridge leading northwest from Carpenters Knob, near the border of Burke, Cleveland, and Catawba counties, corundum in grayish-blue tapering crystals is found associated with garnetiferous gneisses and schists.

*Carter mine.*—Corundum occurs in a peridotite formation associated with spinel. Considerable work was done here ten years ago, but since then the mine has been idle. This locality offers a somewhat promising prospect.

*Celos Ridge.*—Corundum crystals 2 to 3 inches long have been found sparingly in the decomposed gneiss on this ridge 8 miles southeast of Burnsville, Yancey County.

*Chastains Creek*.—See above, under Caney Fork.

*Chunky Gal Mountains*.—Corundum has been found in the bands of quartz-schists and gneiss of which the Chunky Gal Mountains are composed. Garnet is associated with the corundum, which forms a very small percentage of the rock. This occurrence is described on page 34.

*Collins mine*.—Pink corundum in cyanite occurs at this mine near Statesville, Iredell County.

*Corundum Hill mine*.—The corundum at this mine occurs in a peridotite. (See p. 55.)

*Cowee Valley*.—Ruby and red corundum are found in the alluvial deposits of this valley, many of which are transparent. (See description of ruby mine, pp. 40–44.)

*Coweeta*.—Pink corundum is found in a greenish cyanite at this place, in Macon County.

*Cullakeenee mine*.—Same as the Buck Creek mine.

*Cullasagee mine*.—This is the same as the Corundum Hill mine.

*Democrat*.—Corundum has been found, sparingly associated with the peridotite rocks, a little to the south of this place, in Buncombe County.

*Elf*.—Beautiful specimens of pink corundum are found in the green amphibolite. Occasionally there are blue pieces in this rock.

*Egypt mine*.—This mine is located in Yancey County, 10 miles west of Burnsville, and the corundum is in a peridotite. It is in crystalline masses and distinct crystals of a white color, often mottled with blue. This occurrence is interesting as being the only one where corundum has been found surrounded directly by dunite.

*Ellijay Creek*.—Corundum has been found at many points in the valley of this creek, associated with peridotite rocks. The more important of these are the Mincey, Haskett, and Higdon mines.

*Fairview mine*.—At this mine emery occurs in basic magnesian rocks. (See p. 72.)

*Fishhawk Mountain*.—At an elevation of 4,000 feet on the western slope of this mountain, on Hickory Knoll Creek, in Macon County, corundum has been found sparingly in a small outcrop of dunite.

*Foster mine*.—Near the summit of Chunky Gal Mountains, near the headwaters of the northern fork of Shooting Creek, in Clay County, corundum occurs in peridotite. (See p. 60.)

*Gaston County*.—Blue corundum, associated with mica and quartz, has been found at Chubbs, Chowders, and Kings mountains in this county. Emery also has been found at Chowders Mountain.

*Glenville*.—Four miles north of this town, in Macon County, corundum occurs in chlorite-schist similar to that on Caney Fork.

*Gray property*.—Corundum in peridotite. (See p. 58.)

*Grimshaw Gem mine*.—Sapphires of various colors have been found at this mine in peridotite. It is near Montvale post-office, Jackson County. (See p. 45.)

*Hampton mine.*—Same as Mine Fork.

*Haskett mine.*—This is given under Ellijay Creek.

*Herbert mine.*—This mine is on Little Buck Creek, Clay County, and is in a long, narrow arm of peridotite extending out from the main mass of the Buck Creek peridotite formation. Some prospecting has been done here, and although corundum has been found, the main mass of it occurs in connection with the main mass of peridotite.

*Higdon mine.*—This mine was worked for a short time, and there is connected with it a mill for washing and cleaning the ore. (See Ellijay Creek, above.)

*Isbel mine.*—Corundum occurs sparingly in what may be a decomposed amphibolite. One of the largest washing and cleaning mills in the State is at this mine.

*Kings Mountain.*—See Gaston County.

*Marshall.*—Corundum has been found in large gray crystals half mile north of the mouth of Big Ivy River and 3 miles above Marshall, Madison County, on the surface of a large amphibolite outcrop. It is on the property of G. C. Haynie, of Marshall. It has also been found on the property of Hon. J. C. Pritchard near the same town.

*McChristians place.*—Emery of reddish-brown and grayish colors has been found at this place, which is 7 miles north of Friendship, Guilford County. The property lacks development. Surface specimens of corundum have also been found here.

*Mincey mine.*—The corundum at this mine is found in peridotite. (See p. 58.)

*Mine Fork.*—Emery, associated with staurolite.

*Montvale.*—At many of the peridotite formations in the vicinity of Montvale, Jackson County, corundum has been found. (See p. 45.)

*Newfound Gap.*—A little to the south of this gap, in Haywood County, red corundum has been found on the surface of a small mass of dunite.

*Nona.*—Corundum in distinct crystals has been found on the surface, in the vicinity of gneiss, at Nona, Macon County.

*Owens Creek.*—Crystals and grains of corundum have been found in boulders of cyanite near the mouth of this creek, in Transylvania County.

*Presley mine.*—This mine is located 4 miles north of Canton, Haywood County. The corundum, of a blue and bluish-gray color, occurs in a pegmatitic dike.

*Reed mine.*—The corundum at this mine, which is 6 miles east of Franklin, Macon County, occurs in a saprolitic rock, and is in small prismatic crystals of a bluish color, some of which are nearly transparent.

*Retreat.*—Near Retreat post-office, in Haywood County, corundum has been found in limited quantity in small pegmatitic dikes in the gneiss.

*Sapphire.*—The mines in the vicinity of this town are described on page 61.

*Sapphire mine.*—The corundum occurs in peridotite. (See p. 61.)

*Sealy Mountain.*—The corundum occurs in quartz-schist. (See p. 60.)

*Sheffield mine.*—The corundum at this mine is in amphibole-schist. (See p. 58.)

*Skeener Gap.*—Emery is found here in a basic magnesian rock. (See p. 72.)

*Shoups Ford.*—At this place, in Burke County, corundum has been found associated with fibrolite.

*Socrates mine.*—One of the mines in the vicinity of Sapphire. Corundum occurs in peridotite. (See p. 62.)

*Swannanoa Gap.*—Float corundum has been found near an outcrop of peridotite.

*Thumping Creek.*—Corundum has been found in rough nodules and flat crystals in gneiss on the property of Curtis Ledford and C. C. Patterson, on this creek, Macon County.

*Turkey Knob.*—On the summit of this mountain, near the Macon-Jackson county line, corundum has been found sparingly in gneiss.

*Waldroop mine.*—Emery has been found in a basic magnesian rock. (See p. 72.)

*Wataqua mine.*—Same as the Reed mine.

*West Mills.*—Red and ruby corundum have been found in the old gravel beds of the streams on the West farm, near West Mills, Macon County.

*Whitewater mine.*—The corundum is in peridotite. (See p. 63.)

*Winston Salem.*—Near this place, in Forsyth County, emery has been found similar to that at the McChristian place.

*Yellow Mountain.*—The gneisses of this section carry a small percentage of corundum. (See p. 60.)

#### PENNSYLVANIA.

*Blackhorse.*—Slender grayish crystals of corundum have been found at this place, which is near Media, Delaware County. This has been found inclosed by feldspar.

*Fremont.*—Near this place, in West Nottingham Township, Chester County, corundum crystals have been found, surrounded by feldspar.

*Mineral Hill.*—Corundum crystals have been found at this place, which is near Media, in Middletown Township, Delaware County, which were surrounded by feldspar similar to that at Blackhorse.

*Newlin.*—See under Unionville.

*Shimerville.*—At this place, in Lehigh County, corundum crystals up to 8 inches in length and  $4\frac{1}{2}$  inches in diameter have been found loose in the soil.

*Unionville.*—In a large mass of serpentine rocks, 1 mile northeast of this village, corundum has been found. (See p. 66.)

*Villagegreen*.—Large crystals of corundum of a brownish color are found near this village, in Aston Township, Delaware County.

*West Chester*.—Corundum has been found in a serpentine of this township.

#### SOUTH CAROLINA.

*Anderson County*.—Corundum has been reported from this county, but none has been found in place.

*Energy*.—See York County.

*Gaffney*.—Corundum, usually of a gray color and in irregular masses up to 3 or 4 inches in diameter, has been found about 8 miles northwest of Gaffney, on the Island Ford road, near Maud post-office, on the Turner Phillips farm. It has not been found in situ, but in the gravels of a small stream and as loose fragments in the fields on the adjoining slopes. The fragments and what few crystals have been found are generally free from gangue, but some have been found with mica scales attached to them. It is not at all improbable that this corundum was derived from a mica-schist.

*Laurens*.—About  $1\frac{1}{4}$  miles northeast of this town, in Laurens County, corundum has been found rather abundantly scattered over the surface. This surface corundum has been found for a number of miles to the southwest of this town. Although no corundum has been found in place, it was probably derived from a mica-schist, for the country rock in this section is largely a schist, and corundum crystals were found with portions of the mica-schist attached to them. The crystals are all rough, and vary from small ones to some that were over 3 inches long and 1 inch in diameter.

*Oconee County*.—Corundum has been found on the surface in this county, but none has been found in place.

*York County*.—In the northern part of this county, at Energy, near the North Carolina line, a black corundum has been found quite abundantly. (See p. 66.)

#### UTAH.

It is reported that a large deposit of corundum was found in this State during the past year, but no accurate information has been thus far obtained regarding location or quantity.

#### VIRGINIA.

*Louisa County*.—Deep blue crystals of corundum have been found in the soil in this county, but the exact locality is not known.

*Stuart*.—Corundum has been found in a mica-schist near this place on Bull Mountain. (See p. 35.) No development of the occurrence has been made to determine the extent of the deposit or the percentage of corundum.

ALASKA.<sup>1</sup>

*Copper River.*—Asteriated corundum of gray and pink colors is said to occur in a locality on Copper River, Alaska.

## CORUNDUM LOCALITIES IN FOREIGN COUNTRIES.

With the exception of the emery deposits of Turkey and the Grecian Archipelago there were no localities outside of the United States where corundum had been mined for abrasive purposes until during the last year or two, when work was begun at the India deposits. As preparations are being made to work both these and the Canadian deposits on a large scale, it has seemed to me that a short description of them would be of interest and of value. I have also added a short description of the emery deposits of Turkey and the Grecian Archipelago.

## CANADA.

The Canadian corundum localities that are attracting considerable attention at the present time are in the Province of Ontario, and have been recently described by Prof. W. G. Miller,<sup>2</sup> of the Kingston School of Mines. The corundum occurs as a primary constituent of a rock that is classified as a syenite and has been traced for over 50 miles across Renfrew, Hastings, and Haliburton counties, with smaller belts of the same rock in Peterborough, Lanark, and Frontenac counties to the south, making a total distance of nearly 100 miles in which the corundum-bearing rock has been found.

The rock varies from a normal syenite to a nepheline-syenite and a mica-syenite. Corundum has been found in all three of these varieties, but is more abundant in the normal syenite, and this rock has been named corundum-syenite. These rocks, which occur as dikes cutting through the gneisses, are sometimes in large masses that appear to grade into a granite. The width of the dikes varies greatly, but is usually several feet; a few have been observed that were only a few inches wide. These dikes are sometimes thickly studded with corundum crystals. Assays made of this rock from various parts of the dikes indicate that it will average about 12 per cent of corundum. If the corundum can be mined economically, and if tests of the commercial corundum obtained from the ore show that it has the abrasive qualities essential to make it of use in the manufacture of vitrified wheels, these deposits should become of considerable importance.

The Canada Corundum Company, Limited, has been organized and has begun mining operations on the corundum deposits in the extreme northwestern part of Raglan Township, Renfrew County, Ontario, about 7 miles southwest of Combermere. The corundum

<sup>1</sup> Twentieth Ann. Rept. U. S. Geol. Survey, Part VI, 1899, p. 570.

<sup>2</sup> Report Bureau of Mines, Toronto, Can., Vol. VIII, Part II, 1899, pp. 205-240.

here occurs in the normal syenite. A corundum mill has been erected that will have a capacity of 5 tons of cleaned corundum a day.

This company also owns corundum deposits on the York River in Carlow and Dungannon townships, Hastings County. At these localities the corundum occurs in a nepheline-syenite, and while it is apparently of superior quality to that found in Raglan Township, the percentage of corundum is not as high. No mining is being done by the company at these York River localities.

The manager of the company is Mr. B. A. C. Craig, of Toronto, Canada.

Miller<sup>1</sup> has described specimens of corundum from Methuen Township, Peterborough County, that are entirely inclosed by mica. He says: "The corundum is often not observed in the mica until the latter is broken open, when it is found forming the center or core of the mass. The rounded surfaces of the corundum and other characteristics leads to the belief that the masses of light-colored mica are secondary products after corundum." This very closely resembles specimens of corundum surrounded by muscovite mica that have been found at the Presley mine in Haywood County, N. C. (see p. 85), in which the muscovite is undoubtedly a secondary product after the corundum.

In the township of South Sherbrooke, Lanark County,<sup>2</sup> corundum has been found in a rock that is made up of a basic plagioclase feldspar and green hornblende, and has been called anorthosite by Miller. It is more basic in character than the typical varieties of this rock that have been described from other parts of Canada. The width of the belt of rock is nearly three-quarters of a mile and the corundum is found throughout the whole distance. It occurs in crystals of an almost uniform light-gray to white color that are usually about half an inch in diameter, the largest ones being one and a quarter inches long.

#### INDIA.

The corundum deposits of India have been described by T. H. Holland.<sup>3</sup> He gives the Pararapatti area in the Salem district of the province of Upper Burma as one of the most promising for the mining of corundum for abrasive purposes. He describes the corundum as occurring in a matrix of deep flesh-colored feldspar which is in bands or lenticular masses, and has associated with it often a considerable proportion of sillimanite, rutile, opaque black and green spinel, and biotite. These masses, where they have been actually seen in the rock, are sometimes as much as 15 feet long and 8 feet in diameter. The feldspar rock is composed essentially of anorthite and hornblende,

<sup>1</sup> Report Bureau of Mines, Toronto, Ontario, Vol. VIII, Part II, 1899, p. 210.

<sup>2</sup> Loc cit., p. 25.

<sup>3</sup> Geology of India, Part III, Economic Geology, and Report Bureau of Mines, Vol. VIII, Part II, 1899, p. 230.

and in parts has a gneissoid structure, and these portions carry the corundum. The corundum varies from a deep purplish brown to a dark greenish gray, and is in irregular nodules varying from a quarter of an inch to an inch in diameter and in elongated barrel-shaped crystals sometimes an inch long.

There are two and perhaps more of these corundum-bearing bands that are parallel to each other, making the total length of corundum-bearing rock that is known over 24 miles. The percentage of corundum in the rock is very low, experiments that have been made on samples taken at different points on the band showing the presence of only 3.5 per cent.

Most of the outcrops of the bands of corundum rock have been found in connection with gneiss, and lie in lines that are roughly parallel to the strike of the gneiss. Some of them are, however, in close proximity to a nepheline-syenite.

Specimens of corundum sent by Dr. T. L. Walker from a district about 250 miles north of Calcutta and labeled Pipra, South Rewah, India, are apparently similar to those described by Holland. The corundum is very fine grained in appearance and in nodules up to 2 or more inches long by 1 or more inches broad, with a pinkish to purplish-brown color. These nodules are partially or completely surrounded by a greenish mica, whose folia are small and rather brittle, and which has been referred by Mallet<sup>1</sup> to the euphyllite variety. In the mica there are small rough crystals of tourmaline. Just what the occurrence of this corundum is I do not know, but from the general appearance of the specimens it should make an ore from which the corundum could be readily separated and a very clean product obtained. If the corundum in the rock was 10 to 15 per cent of the amount required to be removed in mining, this should make a very important and profitable corundum deposit. A limited amount of this corundum is now being imported by the Norton Emery Wheel Company, of Worcester, Mass., and is used in the manufacture of their India oilstones.

In other specimens labeled Salbanni, 4 miles east southeast of Barampur, Manbhoorn district, India, there are blue crystals of corundum with a rough hexagonal prism embedded in a mass of interlocking bladed crystals of cyanite.

It is very probable that nearly all of the corundum deposits that are known in India are secondary minerals and the result of metamorphism. Professor Judd, in his paper on the Rubies of Burma and associated Minerals,<sup>2</sup> says that all the corundum-bearing rocks in the districts of Southern Asia appear to be gneisses that sometimes pass into schists and frequently contain masses of limestone and dolomite.

<sup>1</sup> Min. India, 1887, p. 130, and Dana's Min., 6th edition, 1892, p. 624.

<sup>2</sup> Trans. Royal Soc., London, 1896, p. 191.

## TURKEY.

The Turkish emery is obtained from the province or vilayet of Aidin, in Asia Minor, which embraces nearly the entire basins of the rivers Sarabat and Mender. Smyrna is the principal town of the province, and is the center of trade for all the surrounding district and islands. The deposits that are now being worked are on the Gumush Dag Mountain and on the slopes of Ak Sivri,<sup>1</sup> which is a mountain about 125 miles to the south. The former of these deposits is about 12 miles east of the ruins of Ephesus, and just north of the river Mender; the latter is in what J. Lawrence Smith<sup>2</sup> describes as the Kulah district, and it is much more inaccessible than the former one. Emery has also been found in small quantities near Adula, a town about 12 or 15 miles east of Kulah, and also at Manser, about 24 miles north, and at Allahinan-Bourgs, about 20 miles south of Smyrna.

The occurrence of the emery at all these localities is very similar, it being embedded in a bluish, coarse-grained to compact marble or limestone, resting upon mica-slates, schists, and gneisses. It always occurs in the limestone or marble; not even a trace has as yet been found in the other rocks. It does not occur in a well-defined vein but in pockets scattered irregularly through the rock that are sometimes up to 200 feet in length and 300 feet in width. The walls of these pockets are very irregular, as the limestone intrudes upon them, and then recedes very suddenly.

## GRECIAN ARCHIPELAGO.

In a number of the islands of this archipelago, emery has been found in considerable quantity. The most important of these localities is the island of Naxos, where the emery is found in large blocks more or less mixed with the red soil, and also embedded in white marble. The deposits are located principally on the north and east sides of the island, the best ore being obtained from Vothrie, which is 9 miles from the coast. Another one of the better deposits on this island is at Apperonthos, which is 7 miles from the coast. In the southern part of the island the emery is found near Yasso. It occurs in such abundance on the island, in loose bowlders and in the soil, that there has been little need to mine it in the hard rock.

On the island of Nicaria emery has been found in quality equal to that from Naxos, but the quantity is not so great. A little was also found on the island of Samos. In all these islands the emery occurs in a limestone.

## OTHER LOCALITIES.

Corundum has been found sparingly at many other localities, but thus far it has not been found in quantity enough to make the occurrences of economic importance as an abrasive.

<sup>1</sup> Trans. Am. Inst. Min. Eng., Vol. XXVIII, 1898, p. 206.

<sup>2</sup> Am. Jour. Sci., 2d series, Vol. X, 1850, p. 357.

The occurrence of sapphire corundum in Burma, Ceylon, and Siam has been mentioned on pages 39 and 46.

Zirkel,<sup>1</sup> mentions the occurrence of corundum as an accessory mineral in the amphibolites of northwestern Austrian Silesia; in the chlorite-schist of Nischne-Issetsk, in the Urals; as a contact product of the diorites of Klausen, in Tyrol; in the andesite and tonalite of the Eifel; in a contact product of quartz-mica-diorite on quartz-phyllite in Val Moja, and similarly in the kersantite of Michaelstein, Harz; also in the graphite of Mühlendorf, near Spitz, in Lower Austria.

Pirsson<sup>2</sup> has mentioned the occurrence of corundum in small blue sapphires in the fresh basalt of Unkel on the Rhine and Steinheim near Frankfort on the Main.

Morozewicz<sup>3</sup> has described the occurrences of corundum in Russia, the chief of which is in a rock composed essentially of anorthite and corundum, together with spinel and biotite. He claims that this is a new type of alumino-silicate rock, and calls it "kysehtymit." Other rocks in the Urals that contain corundum are made up almost exclusively of this mineral and orthoclase; some of these are coarse grained, while others are fine. The coarse ones have been called corundum-pegmatite and the finer ones corundum-syenite. These rocks occur as dikes cutting through gneiss.

It may be that when these corundum-bearing rocks of the Urals have been more specially examined as to their economic value they may be found to contain a large enough percentage of corundum to make them of importance as an ore of this mineral.

Dana<sup>4</sup> mentions the occurrence of corundum near Canton, China; in Bohemia, near Petschau; at Saint Gotthard, in dolomite; near Mozzo, in Piedmont, in white compact feldspar; and at Mudgee, New South Wales.

Laeroix, in a paper<sup>5</sup> on the metamorphic and eruptive rocks of Ariège, France, mentions the occurrence of corundum in the marbles of Mercus and Arignac. In a second paper<sup>6</sup> on acid inclusions in the volcanic rocks of the Auvergne, France, corundum is said to occur frequently in the granites and gneisses of this section. He has also described the occurrence of this mineral in the basic magmas (basalts, trachytes, and andesites) in Haute-Loire, France.<sup>7</sup>

Salomon<sup>8</sup> has described the occurrence of corundum in phyllites, epidote-amphibolites, and mica-schists at Mount Aviôlo, in the Southern Alps. It occurs but sparingly in these rocks.

<sup>1</sup> Lehrbuch der Petrographie, Leipsic, 1893, p. 461.

<sup>2</sup> Am. Jour. Sci., 4th series, Vol. IV, 1897, p. 422.

<sup>3</sup> Tschermaks Min. und Pet. Mitt., Vol. XVIII, pt. 1; and Rept. Bureau of Mines, Toronto, Vol. VIII, Part II, 1899, p. 285.

<sup>4</sup> Min., 6th edition, 1892, p. 212.

<sup>5</sup> Bull. des Serv. d. l. Carte géol. d. France, No. 11, Vol. II; and Am. Nat., Feb., 1891, pp. 138-139.

<sup>6</sup> Loc. cit.

<sup>7</sup> Bull. Soc. Min, Vol. XIII., 1890, pp. 100-106.

<sup>8</sup> Jour. d. d. G. G., Vol. XLII., 1890, p. 450; and Am. Nat., 1891, pp. 571, 572.

In the dune sands on the west coast of Holland, at Sheveningen near the Hague, corundum has been found by Retgers<sup>1</sup> to be one of its constituents.

In describing the geology of the district around Pretoria, South Africa, Molengraaf<sup>2</sup> states that the oldest rocks of the region are granites and crystalline schists. Above these are another series of schist formations, comprising quartzites, clay slates, corundum schists, porphyroids, and chiasolite-schists that are cut by diabase dikes. He states that the corundum porphyroid resembles a feldspar porphyry, and that the corundum occurs in large individuals in a groundmass of quartz and chlorite. From the description given, there is a possibility that there is corundum in quantity in this district.

In many parts of the western Yunnan district, China, as in the prefecture of Shunning Fu, sapphire, ruby, and emerald corundum are said to occur.<sup>3</sup>

---

<sup>1</sup> Rec. des travaux chimiques des Pays-Bas, Vol. XI, 1892, p. 169; and Am. Nat., 1893, p. 382.

<sup>2</sup> Neues Jahrbuch, Vol. IX, 1894-95, pp. 174-291; and Am. Nat., 1895, p. 470.

<sup>3</sup> U. S. Consular Reports, Jan., 1900, Vol. LXII, No. 232, p. 95; reprinted from Mesny's Chinese Miscellany, published at Shanghai, China.



# INDEX.

	Page.		Page.
Acme mine, N. C., corundum at .....	83	Chandlers Hollow, Del., corundum at .....	80
Acworth, Ga., corundum near .....	80	Chase, D., reference to .....	71
Addie, N. C., corundum at .....	83	Chemical wheel, method of manufacture .....	77
Africa, corundum in .....	93	Chester, Mass., emery at .....	23-26, 67-70, 82
Alabama, corundum in .....	79	emery deposit at, map showing .....	68
Alaska, corundum in .....	88	Chlorite-schist, corundum in .....	21
Alps, corundum in .....	92	China, corundum in .....	92, 93
Aluminum, use of corundum in manu- facture of .....	78-79	Chunky Gal Mountains, corundum at .....	34, 60, 84
American Bar, Mont., sapphires at .....	47, 82	Clay County, N. C., amphibolite and corundum in .....	21-22
Amity, N. Y., corundum at .....	82	Cleaning corundum, methods of .....	74-75
Amphibole-schist, corundum in .....	31-33	Colorado, corundum in .....	80
Amphibolite, corundum in .....	21-26	Collins mine, N. C., corundum at .....	84
emery in .....	23-26	Connecticut, corundum in .....	80
Anderson County, S. C., corundum in .....	87	Copper River, Alaska, corundum on .....	88
Andesite, corundum in .....	29-30	Cortland Township, N. Y., emery in .....	70-71
Bad Creek mine, N. C., corundum at .....	62-63, 83	Corundum, cleaning, methods of .....	74-75
Bakersville, N. C., corundum at .....	83	distribution of .....	37-72
Bauer, M., cited .....	43, 54	hardness of .....	10
Beavett mine, Ga., corundum at .....	81	localities of .....	79-93
Belr mine, N. C., corundum at .....	83	mining, methods of .....	72-74
Bell Creek mine, Ga., corundum at .....	80	occurrence of .....	10, 11-37
Belts bridge, N. C., corundum at .....	83	theoretical composition of .....	10-11
Bement, C. S., reference to .....	39	uses of .....	75-79
Betts Gap, N. C., corundum at .....	83	varieties of .....	9
Biotite, corundum in .....	19-20	Corundum Hill, dunite vein at, cross sec- tion of .....	14, 15
Bird, R., reference to .....	49	peridotite at, map of .....	56
Blackhorse, Pa., corundum at .....	86	peridotite formation at, plate show- ing .....	56
Blake, W. P., cited .....	36	sapphires at .....	46-47
Blue, A., cited .....	31	vein at, plate showing .....	56
Bohemia, corundum in .....	92	Corundum Hill mine, N. C., big cut at, plate showing .....	58
Brockton mine, N. C., corundum at .....	61, 83	corundum at .....	55-57, 84
Buck Creek, N. C., peridotite at, map showing .....	22	corundum contact vein at, cross sec- tion of .....	13
peridotite at, plate showing .....	10	rubies at .....	39-40
Buck Creek mine, N. C., corundum at .....	58-59, 83	Cottonwood Creek, Mont., sapphires on .....	51-52,
view of .....	60	.....	82
Buckley, J. H., reference to .....	71	Cowee Valley, N. C., corundum in .....	40-44, 84
Bull Mountain, Va., corundum at .....	35, 87	ruby crystals from, plate showing .....	42
Burnt Rock mine, N. C., corundum at .....	61, 83	ruby mine at, plate showing .....	40
Byram, N. J., corundum in limestone near .....	36	rubies in .....	40-44
Caler Fork, N. C., ruby-bearing gravel at, plate showing .....	40	Coweeta, N. C., corundum at .....	84
rubies near .....	40-44, 83	Craig, B. A. C., reference to .....	89
California, corundum in .....	79-80	Crittenden, H., reference to .....	49
Canada, corundum in .....	88-89	Cullakeenee mine, N. C., corundum at .....	58-59
Caney Fork, N. C., corundum at .....	21, 83	ruby corundum at .....	45
Carpenters Knob, N. C., corundum at .....	83	Cullasagee, N. C., corundum mill at, views of .....	74
Carter mine, N. C., corundum at .....	15, 83	sapphire at .....	46
Celos Ridge, N. C., corundum at .....	83	Cullasagee mine. See Corundum Hill mine.	
Cement wheel, method of manufacture .....	78		
Centralhatchee, Ga., corundum at .....	80		
Chaffee County, Colo., corundum in .....	80		

	Page.		Page.
Cyanite, corundum in .....	36-37	Hamilton mine, Ga., corundum at .....	81
Dalton, O., reference to .....	71	Hampton mine, N. C., corundum at .....	85
Dana, J. D., cited .....	27, 36, 92	Hanover, Ala., corundum near .....	79
Dana Bar, Mont., sapphires at .....	47, 82	Haskett mine, N. C., corundum at .....	84
Delaware, corundum in .....	80	Haynie, C. C., reference to .....	85
Democrat, N. C., corundum at .....	84	Heady, H., reference to .....	71
Diamond, hardness of .....	10	Herbert mine, N. C., corundum at .....	85
Dobson Mountain, N. C., emery at .....	72	Hills, R. C., cited .....	80
Douglas County, Ga., corundum in .....	80	Higdon mine, N. C., corundum at .....	85
Dudleyville, Ala., corundum near .....	79	Hiwassee, Ga., corundum near .....	80
Dunite. See Peridotite.		Hobson, S. S., reference to .....	55
Dunite vein, cross section of .....	14, 15	Hog Creek mine, Ga., corundum at .....	81
open cut on, plate showing .....	58	Holland, T. H., cited .....	89
Dunite veins, plates showing .....	58, 60, 66	Holland, corundum in .....	93
Durrant, J., reference to .....	49	Hunters, N. C., corundum at .....	23
Edman, J. A., cited .....	80	Huntington, Mass., emery at .....	70, 82
Egypt mine, N. C., corundum at .....	15, 84	In Situ Hill, N. C., rubies at .....	41
Eldorado Bay, Mont., sapphires at .....	47, 82	India, corundum in .....	89-90
Elf, N. C., ruby corundum near .....	45	Isbel mine, N. C., corundum at .....	85
sapphires near .....	47	Johnson, C., reference to .....	49
Elf mine, N. C., corundum at .....	84	Judd, J. W., cited .....	90
Ellijay Creek, N. C., corundum at .....	84	King, F. P., cited .....	65
Emerald Bar, Mont., sapphires at .....	49, 82	Kings Mountain, N. C. See Gaston County.	
Emerson, B. K., cited .....	23, 24	Knuth, W., acknowledgments to .....	50
quoted .....	19, 25	reference to .....	49, 50
Emery, distribution of .....	67-72	Kunz, G. F., cited .....	29, 47, 52
in amphibolite .....	23-26	Lacroix, A., cited .....	92
Energy, S. C., corundum at .....	87	Laurel Creek, Ga., dunite vein at, plate showing .....	66
Enstatite, corundum in .....	20	open cut at, plate showing .....	64
Evans, A., information furnished by .....	64	peridotite formation at, map showing .....	64
Fairview mine, N. C., corundum at .....	72, 84	peridotite formation at, plate showing .....	66
emery at .....	72	Laurel Creek mine, Ga., corundum at .....	63-65, 81
Fishhawk Mountain, N. C., corundum at .....	84	Laurens, S. C., corundum at .....	87
Foster mine, Ga., corundum at .....	60, 65, 80, 84	Lawson, A. C., cited .....	80
France, corundum in .....	92	Ledford, C., reference to .....	86
Franklin, N. C., emery near .....	72	Ledford, J., reference to .....	72
rubies near .....	40-44	Limestone, corundum in .....	36
Franklin Furnace, N. J., corundum at .....	82	Litchfield, Conn., corundum near .....	36, 80
Fremont, Pa., corundum at .....	86	Louisa County, Va., corundum in .....	87
French Bar, Mont., corundum at .....	29-30	Lucas, H. S., reference to .....	72
sapphire at .....	47, 82	Macia mine, Mass., emery at .....	68
Friendship, N. C., emery near .....	72	Magpie Gulch, Mont., sapphires at .....	47, 82
Gaffney, S. C., corundum at .....	87	Mann, W., reference to .....	72
Gainesville, Ga., corundum near .....	80	McCoy, Isaac, reference to .....	71
Gallatin County, Mont., corundum in .....	30-31, 66, 82	Marshall, N. C., corundum near .....	85
Garnet, hardness of .....	10	Maryland, corundum in .....	81
Gaston County, N. C., corundum in .....	84	Mason Branch, N. C., rubies near .....	40-44
Genth, F. A., cited .....	35, 37, 72	Massachusetts, corundum in .....	82
Georgia, corundum in .....	63-65, 80-81	emery in .....	67-70
peridotite rocks and corundum, locali- ties, map showing .....	54	Melvin mine, Mass., emery at .....	68
Glenville, N. C., corundum at .....	84	Metropolitan Bar, Mont., sapphires at .....	49, 82
Gneiss, contact between peridotite and, plate showing .....	64	Mica-schist, corundum in .....	34-35
contact vein from peridotite to, cross section of .....	12-14	Miller, W. G., cited .....	31, 88, 89
corundum in .....	33-34	Mincey mine, N. C., corundum at .....	58, 85
cross section of peridotite after intru- sion in .....	15	open cut at, plate showing .....	58
vein between peridotite and, plate showing .....	56	ruby corundum at .....	45
Grecian Archipelago, corundum in .....	91	Mine Fork, N. C., corundum at .....	85
Grimshawe, C., reference to .....	45	Mineral Hill, Pa., corundum at .....	86
Grimshawe Gem Mine, N. C., corundum at .....	45, 84	Minette, basic, corundum in .....	28-29
Gross Ridge, N. C., corundum in gneiss at .....	33-34	Mining corundum, methods of .....	72-74
Habersham County, Ga., corundum in .....	81	Missouri River bars, sapphire crystals from, figure showing .....	50
		sapphires in .....	47, 82
		Moffitt, W., reference to .....	50
		Molengraff, cited .....	93

	Page.		Page.
Monroe, Ga., corundum near .....	81	Retgers, J. W., cited .....	93
Montana, corundum in .....	66-67, 82	Retreat, N. C., corundum at .....	85
sapphire deposits in, map showing lo-		Rock Creek, Mont., sapphires on .....	50-51, 82
cation of .....	46	Ruby, oriental, distribution and charac-	
sapphires in .....	47-53	ter of .....	39-46
Montvale, N. C., corundum near .....	45, 84	Ruby Bar, Mont., sapphires at .....	47, 82
Morozewicz, cited .....	92	corundum in andesite at .....	29
Nannies Mountain, S. C., corundum at .....	66	Ruby-bearing gravel at Caler Fork, N. C.,	
Nevada, corundum in .....	82	plate showing .....	40
New Jersey, corundum in .....	82	Ruby crystals, plate showing .....	42
New York, corundum in .....	82-83	Ruby mine at Cowee Valley, N. C., plate	
emery in .....	70-71	showing .....	40
Newfound Gap, N. C., corundum at .....	85	Sackett mine, Mass., emery at .....	68-69
Newlin, Pa., corundum at .....	66, 86	Salomon, W., cited .....	92
Newton, N. J., corundum at .....	82	Sapphire, N. C., corundum near .....	61-63, 86
Nona, N. C., corundum at .....	85	peridotite areas in vicinity of, map of	
Norite, corundum in .....	26-28	sapphires at .....	47
North Carolina, corundum in .....	53-63, 83-86	Sapphire crystals, figures showing .....	50
emery in .....	72	plate showing .....	52
peridotite rocks and corundum locali-		Sapphire deposits in Montana, map show-	
ties, map showing .....	54	ing location of .....	46
sapphires in .....	46-47	Sapphires, distribution of .....	38-55
Norwich, Conn., corundum near .....	80	varieties of .....	9-10, 39
Oconee County, S. C., corundum in .....	87	Sapphires, oriental, occurrence of .....	46
Old mine, Mass., cross section of .....	69	Saxonite, corundum in contact with .....	19
Oriental ruby, distribution and character		Schal Mountain, N. C., corundum at .....	60, 86
of .....	39-46	Serpentine, corundum in .....	20
Oriental sapphires, occurrence of .....	46	Sheffield mine, N. C., corundum at .....	31-33, 58, 86
Owens Creek, N. C., corundum at .....	85	Shimerville, Pa., corundum at .....	86
Patterson, C. C., reference to .....	86	Shonps Ford, N. C., corundum at .....	86
Peekskill, N. Y., corundum .....	23-28, 83	Silver Peak, Nev., corundum at .....	82
emery near .....	70-71	Skeener Gap, N. C., emery at .....	72, 86
Pelham, Mass., corundum at .....	19, 82	Smith, J. L., cited .....	47, 91
saxonite at .....	19	Snow mine, Mass., emery at .....	69-70
Pennsylvania, corundum in .....	66, 86, 87	Socrates mine, N. C., corundum at .....	62, 86
Peridotite at Corundum Hill, N. C., map		South Carolina, corundum in .....	66, 87
of .....	56	Sphalerite, hardness of .....	38
contact between gneiss and, plate		Spokane Bar, Mont., sapphire at .....	48-49, 82
showing .....	64	Spratt, A. N., reference to .....	49
corundum in .....	11-19	Spratt, F., reference to .....	49
cross section of, after intrusion in		Statenville, N. C., corundum in amphibol-	
gneiss .....	16	lite at .....	22-23
outcrop of, plate showing .....	10	Stone mine, Ga., corundum at .....	81
transition from corundum to, cross		Stuart, Va., corundum near .....	35, 87
section showing .....	17	Swannanoa Gap, N. C., corundum at .....	86
vein between gneiss and, plate show-		Syenite, corundum in .....	30-31
ing .....	56	Teltonville, Ga., corundum near .....	81
vein, contact from gneiss to, cross sec-		Thomaston, Ga., corundum near .....	81
tion of .....	12-14	Thumping Creek, N. C., corundum at .....	33-34, 86
Peridotite formation at Corundum Hill,		Towns County, Ga., amphibolite and co-	
N. C., plate showing .....	56	rundum in .....	21-22
Peridotite rocks in Georgia and North		Track Rock mine, Ga., corundum at .....	65, 81
Carolina, map showing location of		Traphagen, F. W., aid by .....	31
Pine Mountain, Ga., corundum at .....	81	Turkey, corundum in .....	91
Pirsson, L. V., aid by .....	30	Turkey Knob, N. C., corundum at .....	86
cited .....	29, 92	Unionville, Pa., corundum at .....	66, 86
quoted .....	28-29, 32-33	Uses of corundum .....	75-79
Plumas County, Cal., corundum in .....	79-80	Utah, corundum in .....	66, 87
Porter Springs, Ga., corundum at .....	81	Vernon, N. J., corundum at .....	36, 82
Powder Springs, Ga., corundum at .....	81	Villagegreen, Pa., corundum at .....	87
Presley mine, N. C., corundum at .....	85	Virginia, corundum in .....	87
Pritchard, J. C., reference to .....	85	Vitrified wheel, method of manufacture .....	77
Quinn, H. M., reference to .....	71	Vogt, J. H. L., cited .....	27
Rabun Gap, Ga., corundum at .....	81	Waldroop, J. A., reference to .....	72
Reed mine, N. C., corundum at .....	85	Waldroop mine, N. C., corundum at .....	72, 86

	Page.		Page.
Walker, T. L., reference to .....	90	Whitehall, Md., corundum in .....	81
Watauga mine, N. C., corundum at .....	85	Whitewater mine, N. C., corundum at ...	63, 86
Webster, N. C., chlorite schist near .....	21	Williams, G. H., cited .....	26, 27
peridotite at, relation of gneiss to ....	12	Winston Salem, N. C., corundum at .....	86
Weed, W. H., cited .....	52	Wright mine, Mass., emery at .....	67-68
Wells, G. A., reference to .....	55	Yellow Mountain, N. C., corundum at ...	60, 86
West Chester, Pa., corundum at .....	87	Yogo Gulch, Mont., corundum in basic	
West Mills, N. C., corundum at .....	86	minette at .....	28
West Point, Ga., corundum near .....	81	sapphire crystals from, plate showing	52
Wheel, cement, method of manufacture ..	78	sapphires on .....	52-55, 82
Wheel, chemical, method of manufacture ..	77	Zeb Jones mine, N. C., corundum at .....	57
Wheel, vitrified, method of manufacture ..	77	Zirkel, F., cited .....	92











